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HOW TO MAKE AND USE THEM

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

EDITED BY

PAUL N. HASLUCK

EDITOR OF "WORK" AND "BUILDING WORLD"
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PREFACE.

This Handbook contains, in form convenient for everyday use, a comprehensive digest of the knowledge of microscopes and accessories, scattered over more than twenty thousand columns of Work—one of the weekly journals it is my fortune to edit—and supplies concise information on the details of the subjects of which it treats.

In preparing for publication in book form the mass of relevant matter contained in the volumes of Work, much had to be arranged anew, altered, and largely rewritten. From these causes the contributions of many are so blended that the writings of individuals cannot be distinguished for acknowledgment.

Readers who may desire additional information respecting special details of the matters dealt with in this Handbook, or instructions on kindred subjects, should address a question to Work, so that it may be answered in the columns of that journal.

P. N. HASLUCK.

La Belle Sauvage, London,
June, 1905.

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MICROSCOPES AND ACCESSORIES.

CHAPTER I.

CONSTRUCTION OF A STAND MICROSCOPE.

THERE are many persons to whom the possession of a thoroughly good microscope would be of great service, both for amusement and instruction, but who are deterred from purchasing one on account of the first cost, which is necessarily rather heavy. Home workers who have access to a workshop and lathe could readily make a really good and serviceable instrument for themselves; and in this chapter it is proposed to give plain instruction on the making of a cheap and efficient instrument which, when finished, will answer all ordinary requirements.

A diagram enabling the construction of a simple microscope to be easily comprehended is given by Fig. 1, in which A indicates a base of oak hollowed out and filled with lead; B, brass tripod; C, brass uprights; D, lugs; E, stage clips or springs; F, screw and nut on which the microscope proper is pivoted; G, brass support for microscope tube; H J, sliding tubes; M, outer tube containing fine adjustment; Q, thumbscrew with milled edge; P, lower tube supporting mirror T and substage R.

The microscope, whose construction is to be described in this chapter, is shown in elevation by Figs. 2 to 4 (pp. 11 to 13). If castings can be obtained, so much the better; but if not, sheet brass can be used throughout, and as this can be

purchased in almost any locality, it is assumed that this latter alternative is adopted.

From a plate of brass $\frac{1}{4}$ in. thick cut the two legs (Fig. 2), and, after filing them smooth on both sides,

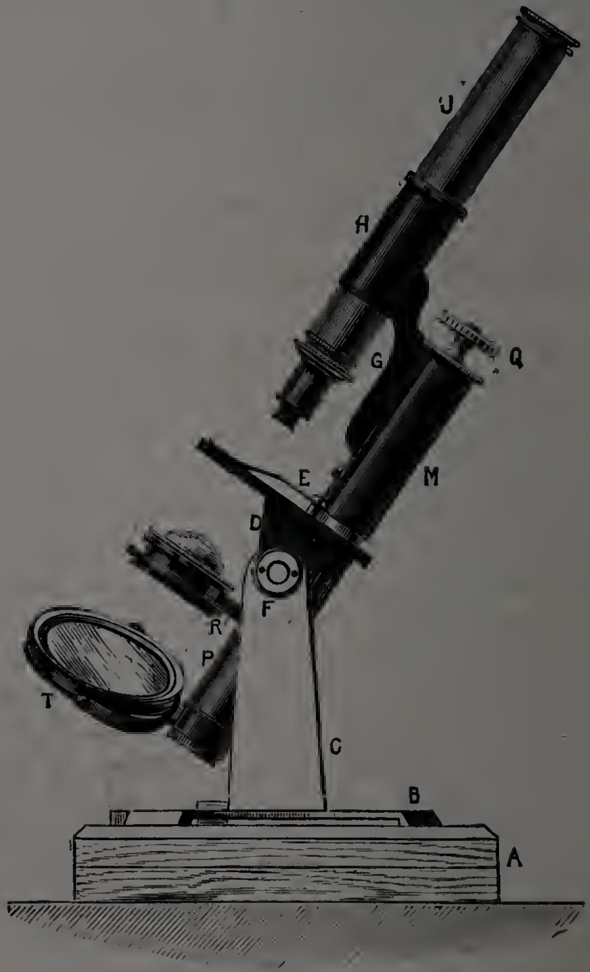


Fig. 1.—Simple Form of Compound Microscope.

solder them together. The edges can then be filed up, holding them between lead clamps in the vice. Before separating them, drill a $\frac{3}{8}$-in. hole; $\frac{1}{2}$ in. from the centre of this hole, and at right angles to it, a smaller hole should be drilled and tapped with a $\frac{1}{8}$-in. thread, as shown in section by Fig. 2. This hole

should go nearly through. From the centre of the large hole, a saw-cut extends downwards about $\frac{9}{16}$ in., and is then continued to the edge of the plate as shown. The small hole is broached out to the saw-cut; the object of this is to allow it to grip the pin upon which the instrument turns when the screw is tightened. Two of these pins are made as shown in Fig. 5 (p. 14). A plate shaped as shown by Fig. 6 is next cut out. It is $\frac{3}{16}$ in. thick, and is screwed to the

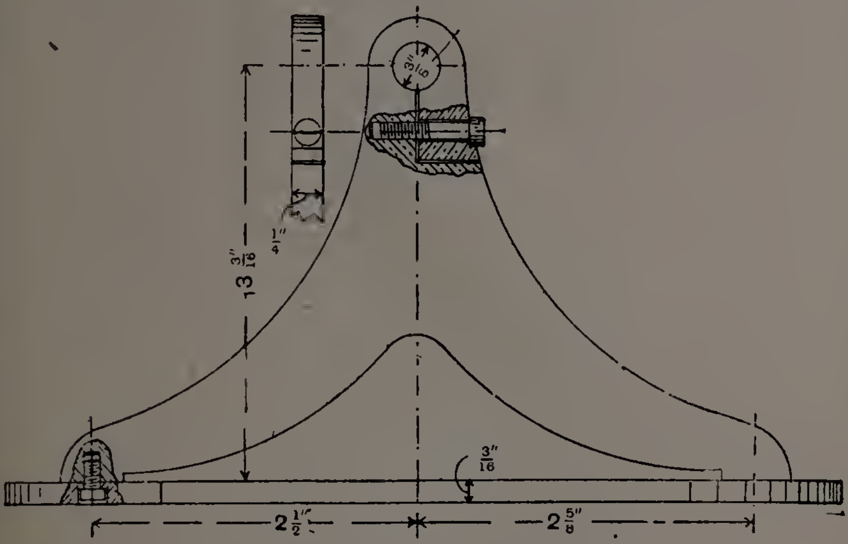


Fig. 2.—Legs of Stand Microscope.

bottom of the two legs (see Fig. 2), and provides a firm base for the microscope.

The stage of the microscope is made from $\frac{3}{16}$-in. brass plate, and cut to the dimensions given in Figs. 7 and 8. In the centre of the square part a $\frac{3}{4}$-in. hole is drilled. Two $\frac{1}{8}$-in. holes are then drilled as indicated by B and C. Next turn the two pins (see Fig. 9). A $\frac{1}{16}$-in. projection is left at the top, to which is riveted a bent slip of thin, hard-rolled brass, D, 2 in. long and $\frac{3}{16}$ in. wide, and tapered towards the end as shown. These pins fit easily into the holes B and C, and hold any object, or a slide, that

may be placed underneath them. At $2\frac{7}{8}$ in. from the left-hand end another hole is drilled and tapped

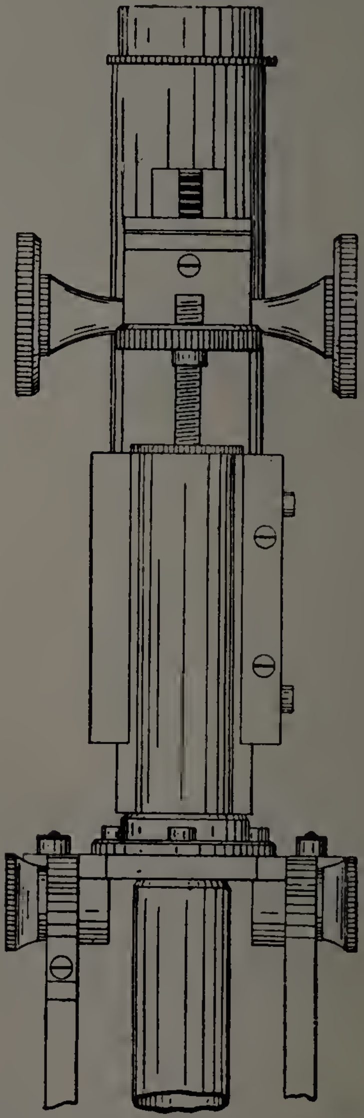


Fig. 3.—Rear Elevation of Stand Microscope.

with a $\frac{1}{4}$-in. fine thread; into this hole is screwed from underneath a short length of $\frac{3}{4}$-in. brass tube, one end of which is plugged with a piece of threaded

brass rod (see Fig. 10). Two semicircular pieces of brass, $\frac{1}{4}$ in. thick, are then hard soldered to the plate; holes in the centres of these pieces (E, Fig. 8) are

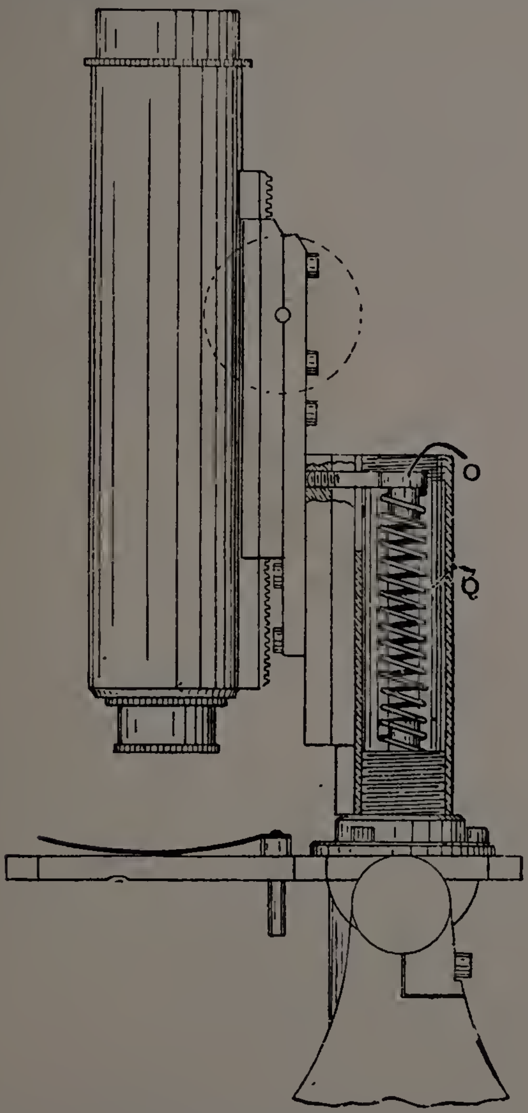


Fig. 4.—Side Elevation of Stand Microscope.

drilled and tapped with a $\frac{1}{4}$-in. fine thread to receive the two pins, one of which is shown by Fig. 5.

The pillar tube and fittings will now be described.

Take a piece of brass tube (Figs. 11 and 12) $2\frac{13}{16}$ in. long and $\frac{3}{4}$ in. external diameter. A fine thread is chased about $\frac{1}{2}$ in. into each end (a pair of chasing tools fifty threads to the inch may be used), and at the top at F a slot $\frac{1}{8}$ in. wide and $\frac{3}{4}$ in. deep is cut. Turn a piece of brass rod or gun-metal to the size indicated at G (Fig. 11); the small end is $\frac{1}{2}$ in. long, and threaded to fit the tube; a $\frac{1}{4}$-in. projection is left at the top. In the bottom of the large part three holes are drilled to take $\frac{1}{8}$-in. screws (see Fig. 4). At the top of this tube a disc of brass is turned and

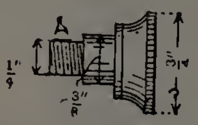


Fig. 5.—Screwed Pin.

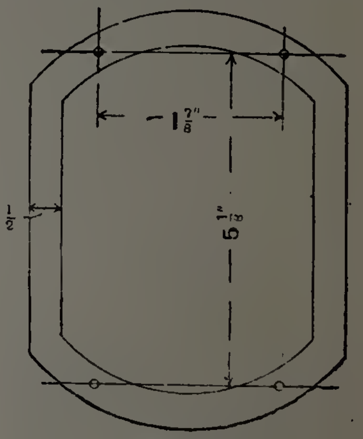
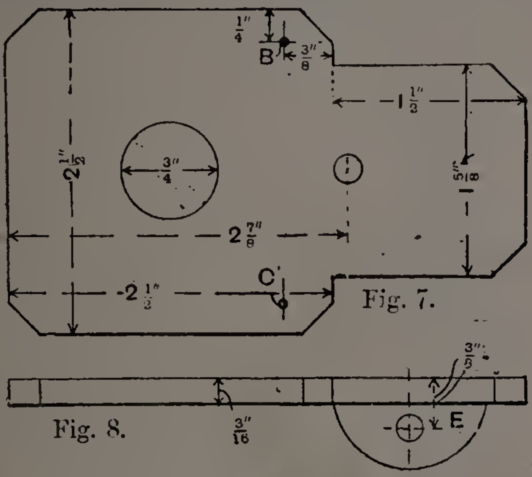


Fig. 6.—Elliptical Plate.

threaded (see Figs. 3 and 11), and in the centre of this disc a $\frac{3}{16}$-in. hole is drilled and tapped with a fine thread, fifty turns to the inch; into this hole the fine adjustment screw H is inserted. This screw should be of steel, and pointed, the head being a disc of brass, with a milled edge.

A plate $\frac{3}{16}$ in. thick, the other dimensions of which are given in Fig. 13, is now cut out, a slot being made at the top to correspond with the slot in the tube. The sides are then filed, to form a dovetail fitting. A circular groove is filed down the centre, and should correspond with the radius of the tube shown by Figs. 11 and 12, to which it is firmly sweated.

The plate of the fine adjustment slide (Fig. 14) is filed smooth and square, and a slip of brass, $\frac{5}{16}$ in. wide, $\frac{3}{16}$ in. thick, and $4\frac{5}{8}$ in. long, is then bevelled off to correspond with the gauge (Fig. 15), and then



Figs. 7 and 8.—Microscope Stage.

sawn in half, one piece being sweated to the plate, the other half being screwed on (see J, Fig. 14). The two holes in this loose slip should then be elongated across the width, so that adjustment may be allowed for after-wear. The method of fixing will be readily understood by referring to the illustrations; the slip is made to slide on the plate shown by Fig. 13. A good, close fitting in all the slides is absolutely necessary, to which end grinding them

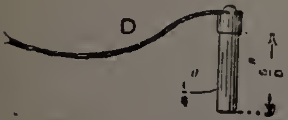


Fig. 9.—Pin with Brass Clip.

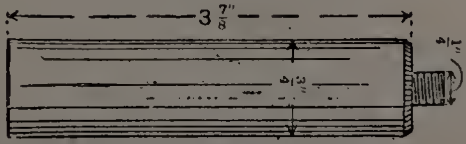


Fig. 10.—Mirror Tube.

with a little pumice-powder and oil, or fine oilstone powder, will help.

The top slide, which is $\frac{3}{16}$ in. thick, is illustrated by Fig. 16. Its centre, which is filed out as shown

in the plan, is $\frac{1}{8}$ in. deep, $\frac{9}{32}$ in. wide, and $2\frac{5}{8}$ in. long, and has a hole K cut through. This hole is $\frac{7}{32}$ in. wide, $\frac{5}{16}$ in. long, and is bevelled inwards. With a small round file a groove $\frac{1}{16}$ in. by $\frac{1}{8}$ in. is cut across the plate on the other side, as indicated by the dotted

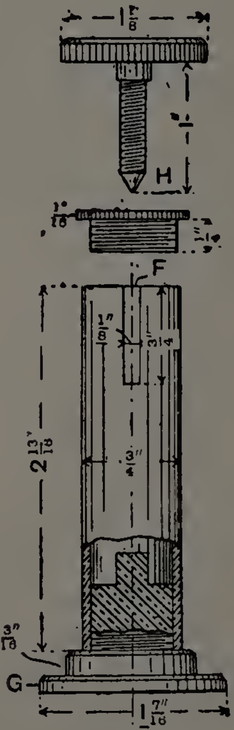


Fig. 11.

Fig. 12.

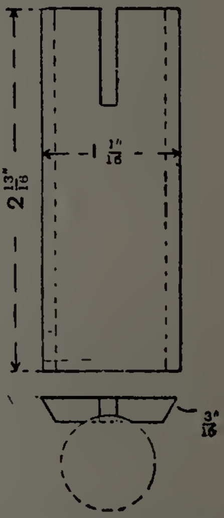


Fig. 13.—Fine Adjustment Slide Plate.

Figs. 11 and 12.—Pillar Tube.

lines. This groove provides a bearing for the main tube adjustment (Fig. 17), which is ground in. Two slips of brass, $\frac{5}{16}$ in. by $\frac{1}{8}$ in., are then filed to the gauge; one piece is sweated on as shown at L (Fig. 16), whilst the other is secured by two $\frac{1}{8}$-in. screws. The underneath part of this slip should be filed away

about $\frac{1}{32}$ in., as indicated by the lines M M (Fig. 16). The dovetail slide, being carefully fitted, will allow the ends to spring on to the slide and take up any wear that may occur when the screws are tightened.

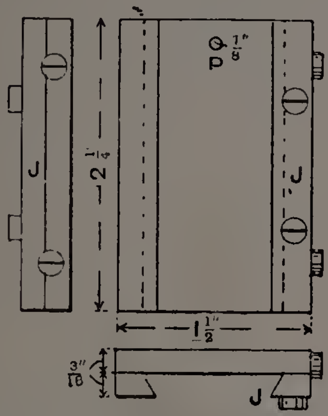


Fig. 14.—Fine Adjustment Slide Plate.

The slide illustrated by Fig. 18 is 4 in. long, and $\frac{5}{32}$ in thick, and has sweated or screwed to its centre a

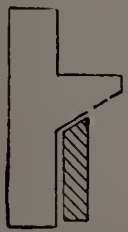


Fig. 15.—Gauge for Bevelled Slides.

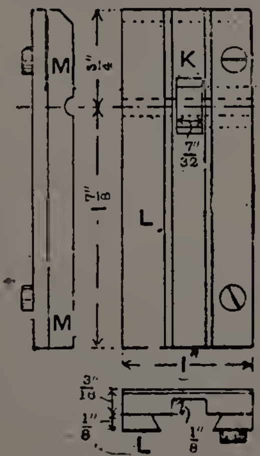


Fig. 16.—Coarse Adjustment Slide.

piece of brass rack which is $\frac{3}{16}$ in. wide, $\frac{3}{32}$ in. thick, and has teeth of $\frac{1}{18}$ in. pitch.

If this rack cannot be bought, it can be made in the following manner. Turn up a piece of round cast

steel $\frac{5}{8}$ in. diameter, 8 in. long, to the dimensions given in Fig. 19, and on the large part cut a thread eighteen to the inch. With a triangular file make a few grooves, diagonally, across the threads to form cutting edges, and then harden and temper the steel. Solder a slip of brass, 4 in. by $\frac{3}{16}$ in. by $\frac{3}{32}$ in., to a plate 4 in. by 6 in. by $\frac{3}{16}$ in. Now allow the new tool to revolve between the lathe centres, and adjust the

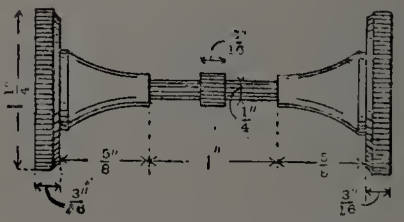


Fig. 17.—Main Tube Adjustment.

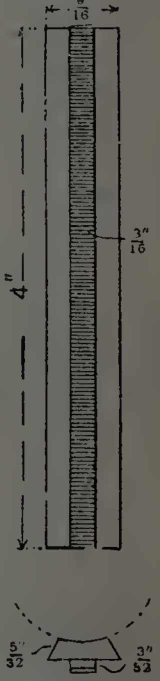


Fig. 18.—Rack Slide.

tool rest, upon which can be held the slip, previously made smooth and parallel. If it is kept in close contact with the quickly revolving tool, the teeth will soon be cut and the rack formed in the same manner as is adopted when chasing a thread. Some care must be exercised, and then good results will be obtained.

The revolving tool can also be employed in making the adjustment pinion. To the centre of a 2-in. length of $\frac{1}{8}$-in. diameter steel rod sweat a disc of brass $\frac{3}{16}$ in. wide and $\frac{1}{4}$ in. diameter. Obtain a piece

of hard wood 3 in. by 2 in. by $\frac{1}{2}$ in., and across its centre file a small groove. Cut a hole $\frac{3}{16}$ in. wide, $\frac{3}{8}$ in. long, and $\frac{1}{4}$ in. deep in the centre of this groove. Into the latter place the steel rod, with the brass disc in the hole; then, by pressing the thumbs on the rod at each end of the pinion and holding the latter underneath and against the revolving tool and at right angles to the lathe centres, the tool will cut, and the pinion will work itself round. Reference to Fig. 19 will simplify this description. Two discs are now turned to the dimensions given in Fig. 17, and screwed on to the steel rod. Before screwing them home, a little solder put upon them will make a firm joint.

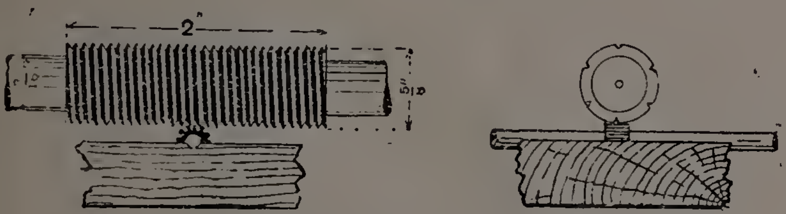


Fig. 19.—Method of Cutting Coarse Adjustment Pinion.

The rack and slide are then sweated to the main tube (Fig. 20), in the position shown by Figs. 3 and 4. This tube is $4\frac{7}{8}$ in. long, $1\frac{3}{16}$ in. outside diameter, and $\frac{1}{16}$ in. thick, and at the bottom a disc of brass is sweated, and turned down. The hole in its centre is $\frac{7}{8}$ in. diameter and chased with a fine thread. Into this the object lens is screwed. The one indicated in Fig. 20 is $\frac{1}{2}$-in. focus. The top part is threaded to screw into the bottom of this tube, whilst the lower piece screws into the part marked N. The following is the method employed for fixing the lens. A hole is first drilled through the centre of the brass disc; in this case the hole is of $\frac{1}{10}$ in. diameter. A circular recess for the lens is then turned out and in it is placed the plano-convex lens, taking care to have the convex side uppermost.

A combined cutting and burnishing tool, $\frac{1}{8}$ in. in

width, of the shape shown in Fig. 21, will now be required. The work is made to revolve in the lathe, and as (with the cutting edge towards the operator) the point of the tool cuts a groove a little larger in diameter than the recess, the polished side will gradually burnish the edge of the brass over towards the lens, thus holding the latter firmly in position.

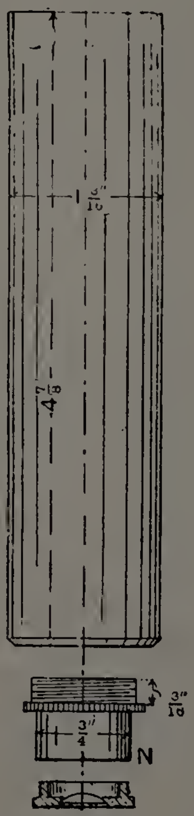


Fig. 21.—Burnishing Tool.

Fig. 20.—Main Tube of Microscope.

The brass should not fit too lightly over the lens, neither should the lathe run too fast, as the heat generated may cause the lens to crack.

A brass plate is now cut to the size and shape shown in Fig. 22, and in its centre a hole is cut, similar to the one at K (Fig. 16). The hole should be bevelled inwards as indicated by the dotted lines in the side view presented in Fig. 22; a groove is also cut

to correspond with the one in Fig. 16, and six holes are drilled to take $\frac{1}{8}$-in. screws. The position of this plate will be seen by referring to Fig. 4. The threaded steel pin O (Fig. 4) is $\frac{1}{8}$ in. diameter, but the large part is $\frac{3}{8}$ in. diameter, the centre being countersunk. It is screwed into the top of the plate P (Fig. 14), and works up and down the slot F (Fig. 11). Q (Fig.

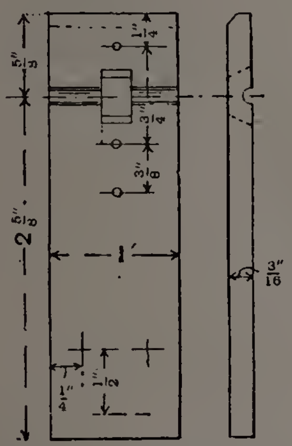


Fig. 22.—Fine Adjustment Brass Plate.

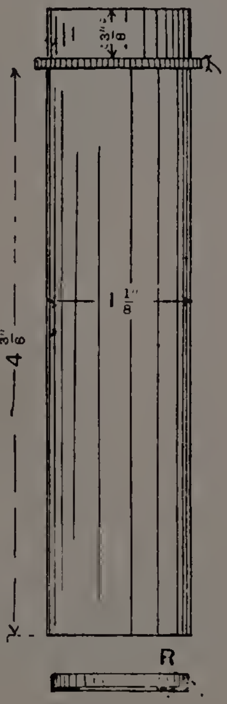


Fig. 23.—Draw Tube.

4) is a stiff spiral spring which should be so adjusted that when in position it keeps the tubes and slides of the microscope at the top of the tube.

The fine adjustment is made by screwing the milled head of the screw H (Fig. 11). The point of the screw enters the countersink in the steel pin, and by screwing this either up or down, very fine adjustment is effected.

Fig. 23 illustrates the power tube or draw tube, which is $4\frac{7}{8}$ in. long, $1\frac{1}{8}$ in. diameter, and $\frac{1}{16}$ in.

thick. It should be put on a mandrel and a light cut taken off with a tool in the slide-rest until it fits easily into the tube (Fig. 20). It should be so fitted that it can be easily raised by the thumb and finger, yet remain firmly in any position required. At $\frac{3}{8}$ in. from the top a $\frac{1}{16}$ in. milled collar is sweated; two stops, as shown at R (Fig. 23), are pushed tightly into the tube. Turn down a piece of thin sheet brass until it enters a $\frac{1}{4}$-in. length of tube, to which it is sweated; fix this on a chuck, and turn the tube down until it fits rather tightly into the power tube. Turn a hole in the disc a little larger in diameter than the lowest power eyepiece. This stop is

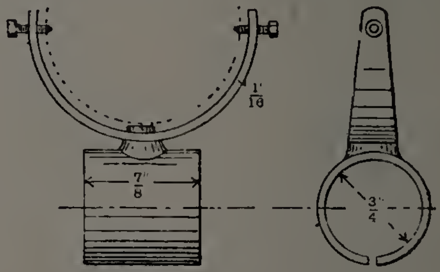


Fig. 24.—Mirror-holder.

placed at the top of the tube, and just below the field lens of the eyepiece; the opening in the bottom stop is about $\frac{5}{8}$ in. diameter.

The support for the mirror is illustrated by Fig. 24, and is now made. It comprises a short length of tube, $\frac{7}{8}$ in. long and $\frac{3}{4}$ in. internal diameter, sawn through longitudinally, and made to slide rather tightly on the tube (Fig. 10, p. 15). A disc of brass, $\frac{3}{8}$ in. diameter at the top, is then sweated on at the centre as shown. Take a slip of brass $\frac{3}{8}$ in. wide, tapering to $\frac{3}{16}$ in. at each end, and $\frac{1}{16}$ in. thick, and at each end tap a $\frac{1}{16}$-in. hole, into which two steel-pointed screws are inserted. These latter support the mirror, which has two small holes drilled diameter-wise, into which the steel-pointed screws enter, and whilst holding the mirror firmly in any position,

allow it to be adjusted at any angle required. In the centre a hole is drilled, by means of which it is screwed to the projecting piece by a $\frac{1}{8}$-in. screw and washer; it is then bent as shown. Fig. 25, below, illustrates the mirror. A disc of $\frac{1}{4}$-in. brass is hollowed out, into which a circular mirror fits; the edge of the brass near the mirror is then burnished over, as previously described. On the other side of this disc fit a concave mirror of 3-in. or $3\frac{1}{2}$-in. focus.

In screwing the fine adjustment tube and slides to the microscope stage, be sure that the central line of the main tube corresponds with the centre of the hole drilled in the plate. If they do agree, mark off

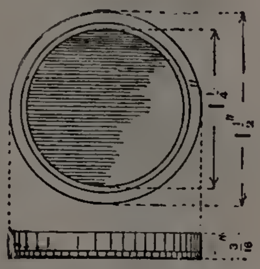


Fig. 25.—Mirror for Microscope.

with a fine steel scriber, and then drill and tap to take $\frac{1}{8}$-in. brass screws.

When all the parts have been constructed and the microscope has been satisfactorily fitted together, it may be taken to pieces and the various parts polished and lacquered (see Chapter III.). The inside of the draw-tube, eyepiece, and object-lens should then be blackened. To do this, mix a little ivory black with gold size or thin varnish, and apply a coat; a dead black is necessary to prevent cross reflection of light.

A substage with condenser is shown in the explanatory illustration (Fig. 1, p. 10), but the instrument just described is not so fitted. However, its attachment would not be difficult. The substage could be made from a short length of tube attached

to the arm supporting the mirror (Fig. 10, p. 15), and it could be moved at any required distance from the object. Into the top of the substage is screwed the condenser, as shown in Fig. 26, and into the bottom a carrier for the various stops used. Fig. 27 shows the form of stop to be used when an object is to be illuminated on a dark field; by using a stop in the shape of a semicircle an oblique light is obtained. Any other apparatus can also be fitted as desired on to the substage.

The moderation of the light is a very important item to ensure good vision in a microscope, as objects

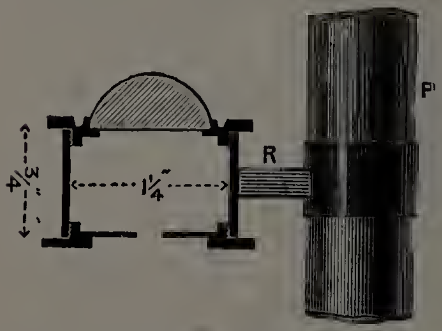


Fig. 26.—Sectional View of Substage and Condenser.

Fig. 27.—Stop for Dark Field Illumination.

often show much more detail under a soft light than under a strong one. It is, therefore, necessary to have some kind of stop fitted to the stage or substage which can be made to shut off superfluous light. The substage just referred to is so fitted. Microscopes usually have a circular plate with holes of various size for shutting off the light; but the iris diaphragm (Fig. 28) is the most efficient stop, but it is usually fitted only to the more expensive instruments.

Its action is as follows:—A shallow box, having a circular aperture the same size as the diameter of the substage condenser, is fitted with a number of movable leaves—from eight to sixteen generally being used—

pivoted in such a manner that, by revolving the lid of the box a quarter-turn, they can be made either to open or contract over the aperture, and admit or shut off light to any degree required.

Fig. 28 shows the box A, with the top removed; B, the aperture; C, one of the movable leaves. Fig. 29 is a sectional view. This leaf is pivoted to the

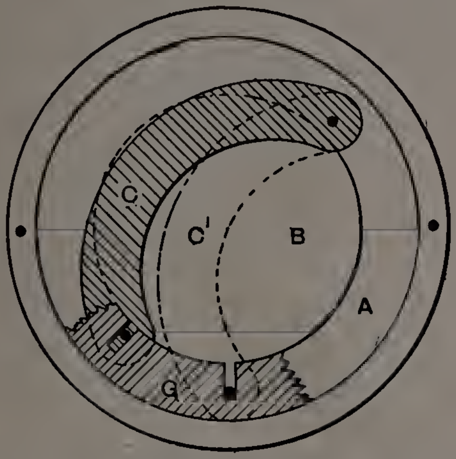


Fig. 28.—Iris Diaphragm with Lid Removed.

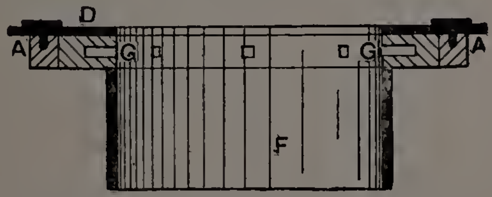


Fig. 29.—Section of Iris Diaphragm.

box at one end, and a pin at the other end works in the slotted disc G (Figs. 28 and 29). The position of C at the shaded part shows how one leaf would be if half the aperture were closed; whilst at C^1 nearly all light would be shut off by the eight leaves.

These leaves have to be cut out of very thin, hard, rolled brass; they can be cut with the shears, but the best method would be to cut out four rough circles a trifle larger than 1 in. in diameter, and turn

them true in the lathe as follows :—Having turned up true on the chuck a wooden face-plate, cut out another ring in hard wood, 1 in. in diameter and $\frac{1}{4}$ in. broad ; drill a hole at each side, then take the four thin circles, drill the same as the wooden ring, and screw them on to the face-plate with the ring over them. The edges can then be turned true. and the centre cut out, leaving four brass rings of the required width for the eight leaves with rounded ends. When all are cut to the same size, place together and drill a hole at each end for the pivots and pins.

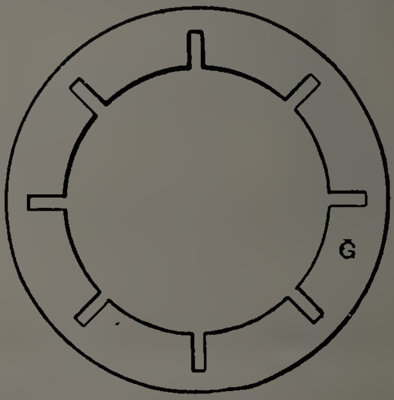


Fig. 30.—Slotted Ring of Iris Diaphragm.

These are made out of thin brass wire, soldered one at each end, a pivot on the bottom, and a pin on the top of each leaf.

The box shown in section at Fig. 29 can be made out of a casting, or a brass ring can be soldered on a thin disc, with the centre cut out the required size, and countersunk to take the leaves. Mark it off into eight divisions, and drill a hole in the centre of the part A (Fig. 28) at each mark to fit the pivots. Cut out another ring, as at Fig. 30, to fit in the box ; make eight slots as shown for the pin on the top of each leaf to fit and slide in. This slotted ring is to give the necessary motion to the leaves. It is soldered on to the bottom of the lid of the box D

(Figs. 29 and 31), this being retained in its place by the two screws E working in slots cut in the lid. A piece of brass tubing F (Fig. 29) is fitted to the bottom of the box to hold the iris diaphragm in the stage or substage of the microscope. The leaves open and close by simply turning the lid.

The more leaves used in the iris diaphragm the more nearly circular will be the aperture made by them, and the smaller will be the pinhole in the centre when all the leaves are closed. Figs. 28 to 31 are two-thirds full size.

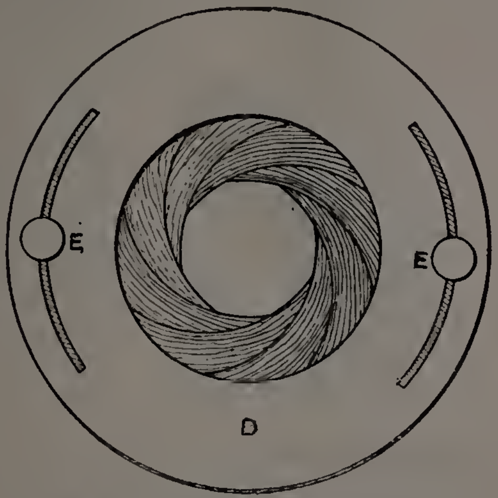


Fig. 31.—Plan of Iris Diaphragm.

Many workers will not consider the microscope complete unless it be fitted with a mechanical stage; the construction of this most useful attachment is considered in the next chapter.

Instructions on making a microscope will not be complete until it has been shown what lenses will have to be used. Telescope and microscope eyepieces have much in common, but on a telescope a much higher power can be used than on a microscope. A long focus object-glass is used in a telescope, and consequently does not magnify the image to any great extent; the main magnification is made by

the eyepiece. In the microscope the object-glass is of short focus, and consequently magnifies the object in proportion. For example, suppose normal sight is 10 in., then, by using a lens which has a focal length of 5 in., the eye is brought twice as near to the object, and consequently the object will appear twice as large. Or, by using a $2\frac{1}{2}$-in. lens, the diameter will be magnified four times, and so on, up to $\frac{1}{2}$ in., or other high power. Of course, a high-power eyepiece could be used with any object-glass. But there is this drawback: in all object-glasses of high power except those of the highest possible

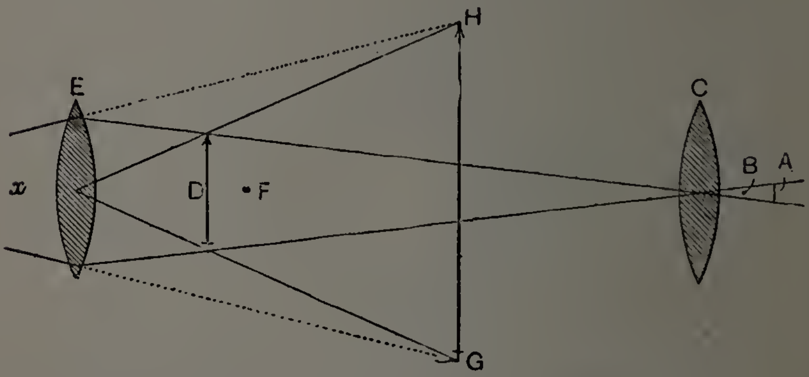


Fig. 32.—Optical System of Compound Microscope.

quality, there will be some little defect; and to use a high-power eyepiece in a microscope would be to magnify the image of the object, defects and all.

The reader unacquainted with optical matters will need some information on the lens system of a compound microscope before its principles will be apparent to him. A simple microscope is a magnifying glass consisting only of a double convex lens, but a compound microscope must have two lenses, and at least one of these will be formed of two or more glasses. In the diagram (Fig. 32), assume the short line A to represent the object being viewed. It is placed somewhat beyond the principal focus B of the object lens C, and an inverted and enlarged

image of it is formed at D in the conjugate foci. (The reader need not be troubled with definitions of these terms, the diagram being all-sufficient in enabling the bare principle to be grasped.) The eyepiece lens E is so adjusted that the inverted image is between the eyepiece's principal focus F and the eyepiece, and this causes the image to be further enlarged to G H. Thus, the object A under-

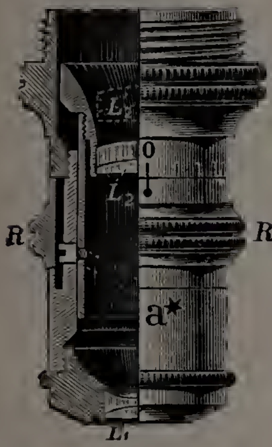


Fig. 33.—Zeiss Objective with Correction Collar.

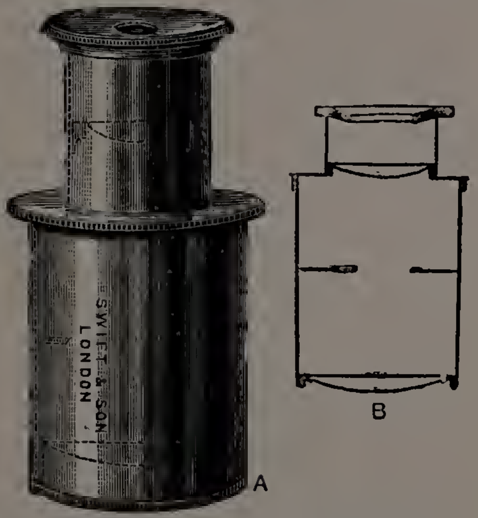


Fig. 34.—General and Sectional Views of Huygenian Eyepiece.

goes two distinct magnifications. The point x indicates the position of the observer's eye. The objective in a plain microscope is a single glass (as in the diagram, Fig. 32), which can be brought close to or away from the object being viewed. In elaborate instruments, the objective may be a compound lens, as in Fig. 33 for instance, this showing a Zeiss objective with correction collar. The eyepiece usually is formed of two or more glasses so as to obtain greater distinctness in the image, but their combined effect is the same—as far as the principle is concerned—as that of the single glass shown in the diagram (Fig. 32). The most general

form of eyepiece is the Huygenian (A and B, Fig. 34), consisting of two plano-convex lenses having a stop between them. The plane surfaces are towards the observer's eye.

Eyepieces for the microscope are sometimes designated A, B, C, D, etc. They consist of two lenses; a large one nearer the object-glass, called the field lens, and a small one nearest the eye, called the eye lens.

A general rule for diameters is that the field lens should be twice that of the eye lens; thus, if the field lens is 1 in. in diameter, the eye lens should be about $\frac{1}{2}$ in. in diameter. The rule for focal length is that they should be as two to one; thus, if the field lens is $1\frac{1}{2}$ in., then the eye lens must be $\frac{3}{4}$ in. These are placed with their plane side towards the eye, and one-half of their combined focal length apart; thus, $1\frac{1}{2} + \frac{3}{4} = 2\frac{1}{4} \div 2 = 1\frac{1}{8}$, so that they would be $1\frac{1}{8}$ in. apart. A stop must be placed between these at the focus of the eye lens, the opening the same as its diameter.

To determine the focal length of the eyepiece, proceed as follows: Multiply the focal length of the lenses into each other, and then by two, and divide the product by the focal lengths when added together: thus, $1\frac{1}{2} \times \frac{1}{2} \times 2 = 1\frac{1}{2}$; $1\frac{1}{2} + \frac{1}{2} = 2$; $1\frac{1}{2} \div 2 = \frac{3}{4}$, so that the eyepiece constructed by these lenses would be $\frac{3}{4}$ in. focal length.

The following is given by a manufacturing optician:—

(1)	Eye lens, $1\frac{1}{2}$ ..	Field lens, 3 ..	Distance apart, $2\frac{1}{4}$
(2)	,, ,, 1 ..	,, ,, 2 ..	,, ,, $1\frac{1}{2}$
(3)	,, ,, $\frac{3}{4}$ ..	,, ,, $1\frac{1}{2}$ ..	,, ,, $1\frac{1}{8}$
(4)	,, ,, $\frac{1}{2}$ ..	,, ,, 1 ..	,, ,, $\frac{3}{4}$

The graduated screw-collar constitutes an important adjunct to the use of the microscope. It has been noticed that a very decided difference exists in the precision of an image when the object is viewed with and without a covering of glass, and according

as this cover-glass is thin or thick. This difference increases in proportion to the widening of the aperture, hence becoming a source of error. The remedy consists in making the distance between the front combination and the two posterior combinations of the objective capable of adjustment, thus under-correcting the former and over-correcting the latter. The effect obtained by increasing the distance between the front lens and the object, and by approximating it to the next combination, is that the excess of positive aberration is more strongly exerted upon the other two pairs of lenses than under contrary conditions. In this way is neutralised the negative aberration produced by the covering of glass interposed between the objective and the object.

Low-power objectives with small angles of aperture do not need this adjustment, which, however, is always provided when the angle exceeds 50°. With objectives constructed for students the custom is generally to adjust the instrument originally for objects covered with glass of a standard thickness, say 0·005 in. or 0·004 in., and not for uncovered objects. Departures from that standard by one or two thousandths of an inch are scarcely perceptible with an objective having an aperture of 90° or 100°; but it would be extremely injurious to the performance of objectives of 125° aperture or more.

The screw-collar adjustment is also absolutely necessary to correct the defects caused by the different media employed when the lens is used as an immersion objective. Water, oil of cassia, etc., are used for immersion work; they have different refractive powers, and consequently each requires particular correction.

The adjustment, whether the objective is used wet or dry, is obtained in the following way. Taking the immersed object as an example, it is placed on the stage of the microscope, and brought to focus with a 1-in. or other low power objective, so that it may

be seen whether the object is sufficiently illuminated. Then the low power objective is removed, and the objective with the screw-collar adjustment is substituted for it. A drop of distilled water, or such fluid as is intended for use, is placed on the side and another on the front lens of the objective, which is then racked down until the two drops touch. Then the object is gradually brought with the fine adjustment screw as sharply into focus as possible. When the illumination is quite satisfactory, the collar is moved gently through a very small portion of a turn. The object is now re-focussed with the fine adjustment. Proceeding in this way alternately, either forwards or backwards, with the collar and the fine adjustment, the finest definition is found, repeated trials being made before the best result is achieved. This must be done each time the objective is used with immersed objects. The graduations on the collar indicate the degree of correction required. A record of the separate results would shorten the process should it be again desirable to observe any particular immersed object.

x slide

CHAPTER II.

MAKING AND FIXING MECHANICAL STAGES.

In the construction of a mechanical stage for the microscope the materials required are few; and the following brief description will, it is hoped, enable the work to be carried to a successful issue.

Assuming that the clear part of the stage of the microscope under consideration is $2\frac{1}{2}$ in. square and $\frac{1}{8}$ in. in thickness, there will be required two pieces of

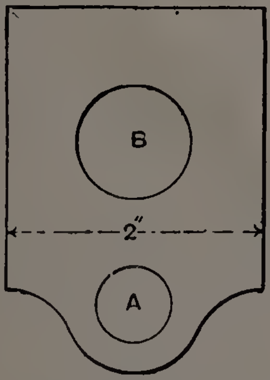


Fig. 35.

Fig. 36.

Figs. 35 and 36.—Plan and Section of Microscope Stage.

brass—$2\frac{3}{8}$ in. by $3\frac{7}{8}$ in. and 3 in. by 2 in. respectively, each $\frac{1}{8}$ in. thick; two strips $\frac{1}{8}$ in. by $\frac{5}{8}$ in.; two strips $\frac{1}{8}$ in. by $\frac{1}{4}$ in.; four strips $\frac{1}{8}$ in. by $\frac{1}{4}$ in.; about a dozen $\frac{3}{32}$-in. screws, with tap to match. A length of pinion wire and 4 in. of rack will also be needed.

Having disconnected the stage (Fig. 35) from the instrument, the first operation consists in bevelling its two sides as shown at Fig. 36, care being necessary that the edges are parallel with each other. Take

the piece 3 in. by 2 in. (P, Figs. 37 to 39), dress up the edges square and straight, and bevel the two long sides. In Fig. 37 X, X, X are the dovetails into which the standards C, C (Fig. 38) are soldered. The remaining piece, $3\frac{7}{8}$ in. by $2\frac{3}{8}$ in., is worked to

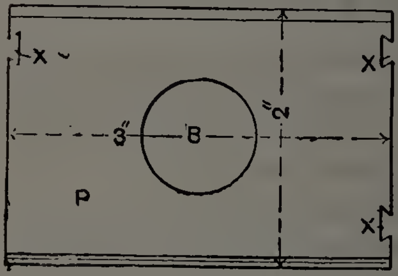


Fig. 37.

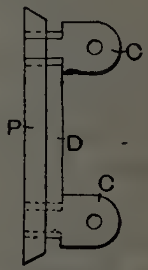


Fig. 38.

Figs. 37 and 38.—Slide Plate for Mechanical Stage.

the dimensions and shape given in Fig. 40. The strip $\frac{1}{4}$ in. by $\frac{1}{8}$ in. can now be filed up flat and smooth, and bevelled to the same angle as the plates just completed.

Referring to Fig. 37, strips are to be screwed at each of the two unbevelled sides (see D, D, Figs. 38 and 39), so that the plate will slide to and fro on the stage (as shown at F) smoothly, but without shake. The best way to secure this is to screw one strip tightly and permanently down, and do all the adjusting with the other, bearing in mind that, if made too tight a fit in the first instance, a little easing will put matters right,

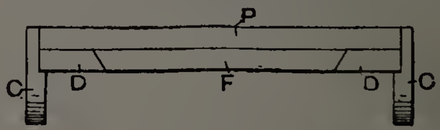


Fig. 39.—Plan of Slide Plate for Mechanical Stage.

whereas if made too slack it will be rather more difficult to remedy.

The plate shown in Fig. 40 is now to be fitted in the same manner, so that it moves from side to side upon the slide just completed. It must, of course, be

understood that all the bevels are to be finished to a fine and polished surface, as upon this depends, to a great extent, the smooth and satisfactory working of the apparatus in practical use. A dovetail slot is cut similar to x (Fig. 37), and tapped to fit the screw (Fig. 41). A nut N (Fig. 42) prevents the screw (Fig. 41) from endlong movement.

The next thing to be considered is the means of giving motion to the slides. In the case of the bottom one (Fig. 37) this is effected by means of a rack and pinion. The pinion is fitted to the slide by means of a short standard or plate of flat brass at each end. The pinion, with its milled head, is shown at Fig. 43.

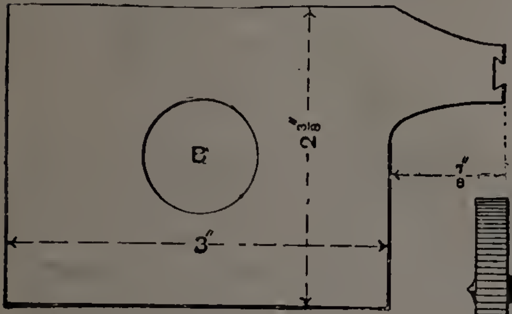


Fig. 40.—Brass Plate.

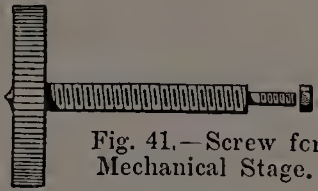


Fig. 41.—Screw for Mechanical Stage.

The rack (H, Fig. 42) is adjusted to gear with the pinion, and either screwed or soldered to the under part of the stage. A small standard is now fitted at a right angle to the projection of Fig. 40, and is tapped with a ¼-in. screw thread. A similar standard is also fixed to the lower slide, and is drilled with an ⅛-in. hole. When the slides are in position, these two holes must come exactly opposite each other, the tapped hole taking a milled head ¼-in. screw (Fig. 41), whose small end passes through the other standard, and is held with a small nut or pin, so that, although free to revolve, it has no lateral movement. A and B (Figs. 35, 37, and 40), agree with A and B (Fig. 42).

Fig. 42 gives a view of the stage as seen from below. A shows hole or socket of instrument; B, aperture for lightning objects; C, standards carrying the pinion wire W, working in the rack H H, by rotation with

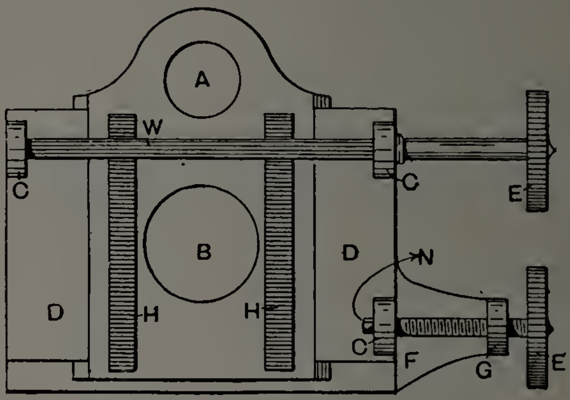


Fig. 42.—Underneath View of Stage.

the milled head E; D, bevelled strips of the lower slide; F, projecting arm of the top slide (Fig. 40), with its standard G, and the screw tapped into it, the end being passed through the standard C, and fastened with a nut N. On the top slide should be fitted the two springs, usually found on a microscope stage, for the purpose of clamping slides under examination.

To fit the whole together, slide the brass plate shown by Fig. 37 upon the stage shown by Fig. 35, as shown in Fig. 39, and fasten in the pinion as shown

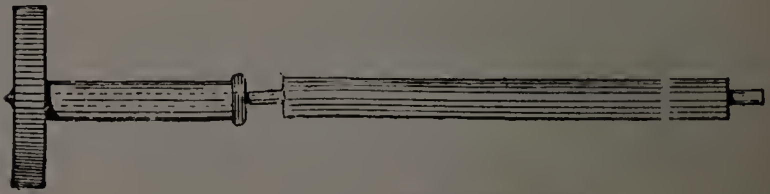


Fig. 43.—Pinion for Mechanical Stage.

n Fig. 42. On rotating the milled head E (shown separately at Fig. 43), it will slide to and fro. Next slide Fig. 40 upon Fig. 37 and fit the milled-headed screw (Fig. 41) as shown; the revolution of this will

cause the slide to travel from side to side. The rotation of either or both the milled heads will therefore give any movement desired, and causes the object under examination to pass slowly and steadily in any desired direction.

The mechanical stage has disadvantages as well as advantages, and in order to reduce the former to a minimum, all fittings should be constructed with as much skill and care as the worker can put into them,

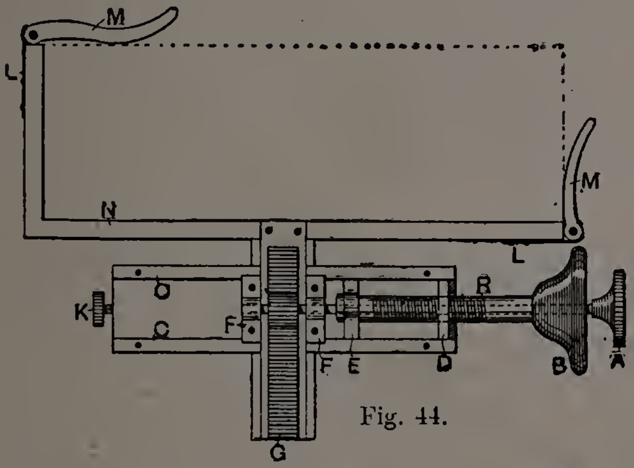


Fig. 44.

Fig. 45.

Figs. 44 and 45.—Plan and Side Elevation of Mechanical Stage.

as any badly-fitted parts in a mechanical stage will be the cause of great annoyance, owing to the need for constantly adjusting the fine focussing screw, on account of the object having moved out of the plane of the focus. Another style of mechanical stage will now be described.

The plan, side and end elevations, presented by Figs. 44 to 46, show a mechanical stage for use with any microscope, to the principal stage of which it is clamped with the screw K. The parts are shown two-

thirds full size, but the width must necessarily be made to fit that of the microscope stage, as shown by the dotted line. There should also be quite 2 in. distance between the optical axis of the microscope and the front of the body, to allow space for the rack slide G to work.

The chief parts of the stage consist of the two sliding movements, at right angles to each other; the one worked by the rack and pinion G and H and the milled head A, the other by the screw and milled head B. The screw B is drilled to allow the shank of the pinion to pass through it; F, F show the bearings of the pinion. The lug D, in which a screw-thread is cut, is fixed at the end of the stage, the

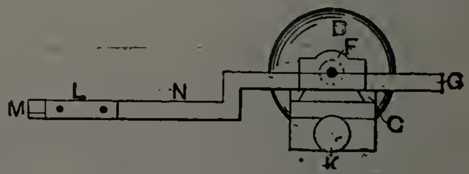


Fig. 46.—End Elevation of Mechanical Stage.

screw R working through it against the bearing E, pushing the same, together with the whole of the upper slide, backwards or forwards.

The mounted object is fixed to the bar N by the two clips M, M, which are made to clip by the springs L, L at the back, working like the blade of a pocket-knife. The bar N with the slide G could be built up of sheet brass, or a casting could be made for a few pence if a pattern were taken to a brassfounder's. Sheet brass can be used for all the other parts, and a piece of brass bar or tube for the screw. Small screws, as used in clockmaking, will be required for fixing the bearings. The two guides C should be made apart from the base of the stage, to which they are fixed by four small rivets or screws. The springs L, L can be made from thin brass, hammered to impart the necessary spring to the metal.

CHAPTER III.

FINISHING AND LACQUERING MICROSCOPE BRASSWORK.

It must be understood that a lacquer is applied to the surface of brasswork for the purpose of improving its appearance and preserving a polish that has already been obtained, and is not intended to impart a brilliant lustre to old and tarnished brass, as some may imagine. The lacquer is simply a form of varnish which prevents the freshly polished surface of the metal from becoming tarnished by exposure to the atmosphere. In point of fact, the operation of lacquering newly polished brass detracts slightly from its appearance, but as the metal would soon corrode and turn black if exposed to the air, it becomes necessary to protect the surface by a coat of lacquer, which, if good, will retain its colour and resist the action of the atmosphere for a number of years. The process of lacquering is rather difficult to execute properly, especially on large surfaces, when the beginner will find the lacquer continually getting a smeary look; but after a little practice, it will be possible to lay on an even coat of lacquer free from streaks, the great difficulty being to know the exact degree of heat best suited to the particular lacquer in use, and the effect to be produced, this kind of knowledge being such as can be obtained only by personal experience.

In all cases where the work consists of a number of parts fitted together, it will be necessary to unscrew or separate the parts and arrange them in such a manner that each screw, etc., can be returned to its respective place without difficulty. To prevent mistakes, it is advisable to number each piece of brasswork on the under side.

For finishing off coarse or common class new work, such as rough castings, which it is wished to protect from tarnishing or oxidising by a coat of lacquer, first wash the metal thoroughly in hot water with plenty of washing soda, using a stiff brush in order to free it entirely from all traces of grease. Rinse it well in cold water, and then dip the articles in a pickle composed of equal parts of nitric acid and water, until they are covered with a white coating resembling curdled milk, when they are quickly removed and rinsed in a large vessel of clean water, being afterwards dried in hot boxwood sawdust. The sawdust should be kept in a tin biscuit box, which can be placed over the kitchen oven to warm, and when the brass is dropped in among the sawdust, the box should be well shaken, in order that the article may be quickly dried. On being removed the metal will be found to have acquired a splendid lustrous appearance, and may be lacquered forthwith; or, if desired, the more prominent portions of the work can be smoothed by means of a flat file, which is held as nearly horizontal as possible; go over the surface first with a second cut file, then with a smooth, and then with a dead smooth file. The work is brought up to an even grain by means of Oakey's emery paper, in the following degrees of fineness: Nos. F, F F, and O.

In order to preserve the colour of the brass up to the moment of lacquering, it will be advisable to dip it in a little commercial nitric acid to which a small quantity of cream of tartar has been added, the article being immediately afterwards rinsed in clean water to remove all traces of the acid, and then dried in hot sawdust, the dust being afterwards brushed off with a dry soft brush, and the article lacquered as quickly as possible.

In the case of old work which has been previously lacquered, such as the lens mount of a microscope or camera, it will be necessary first to unscrew the lens

cells and separate the inner tubes from the outer jackets, being particular to note the position of the various parts. When thus separated, boil off the old lacquer in a lye made by mixing $\frac{1}{2}$ lb. of potash with a gallon of water, the work being allowed to remain in this lye for about twenty minutes, when it should be taken out and immediately plunged into clean cold water, which will have the effect of removing the whole of the old lacquer. It is then taken out and brushed with a clean brush, and if considerably tarnished, it should be dipped in a pickle as before described, which will eat away all the outer coating of corrosion and leave the surface of clean brass. When quite bright and clean it is removed from the pickle and thoroughly rinsed in clean water. If running water is to hand, so much the better; if not, it will be found necessary to have several vessels of clean water handy, so that the work may have a good rinse in all of them, and on being removed from the last water, it is transferred to the sawdust box, from which it is taken in hand to be polished and lacquered.

It is advisable to conduct the operation of dipping out in the open air, or in a well-ventilated apartment, as the fumes given off by the nitric acid are very baneful to health; but where ordinary care is exercised, there need be no fear of danger. Those who object to the fumes of the nitric acid may use the following pickle, which has no unpleasant smell: Make a saturated solution of bichromate of potash with boiling water, and (when cold) add 1 oz. of sulphuric acid slowly to every $\frac{1}{2}$ pint of solution. Do not add the water to the acid or pour the latter into the hot solution, as it might be attended by serious consequences.

If an article has to be handled after dipping or polishing, it should be held in rag in the hand, or suspended on a piece of wire bent in the form of a hook, or it may be held between a pair of tweezers,

a strip of wood slit longitudinally being a capital substitute for the latter. A brass or copper wire of about No. 10 B.W.G. may be bent into the form of a hook similar to Fig. 47, and used for the purpose of hanging the articles on while dipping, flat brass plates being placed on a wire holder similar to Fig. 48. As stated above, it is necessary to avoid handling the work during the operation of dipping, etc., as the slightest trace of grease from the fingers will spoil the after process of lacquering.

In preparing new microscope fittings for lacquering —or in fact, any work for which a superior finish is required—it will be necessary first to scrape up the curved edges of the various parts, holding them in the hand, or clamping them in the jaws of a vice between two pieces of sheet lead or leather. The tool employed for this purpose will be a scraper,

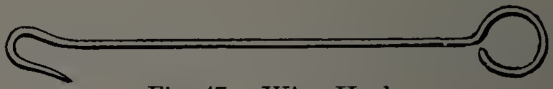


Fig. 47.—Wire Hook.

which is simply an ordinary triangular file, the sides of which have been ground up smooth and sharp on a grindstone, the edges being set on an oilstone until they are sufficiently sharp to take off clean bright shavings. All the flat surfaces and straight edges of the work must be smoothed by means of a dead smooth file, which will obliterate all traces of the previous file-marks. When this has been done, take a piece of emery paper (not cloth) and use this to get rid of the file marks, wrapping it round an old smooth flat file or a thin strip of wood, having previously cut the paper to a size about an inch less in length and about three times the width of the file or wood, in order that it may be wrapped round it and held in position by the forefinger of the right hand whilst in use, being particular to rub in one direction only, and continue the process until all traces of the

file marks have disappeared, when a finer emery paper may be substituted, until the finest (or flour) emery is finally used to obliterate the marks made by the previous paper. If a drop of oil is now smeared over the surface of the brass the grain may be brought up to a smooth and even semi-polish. It will be necessary to clear away carefully all traces of emery dust before using a finer paper, otherwise ugly scratches will continually appear on the surface of the work, only to be removed by going back a step and doing the work again. After the finest paper the finish will be very good, but it can be further improved by rubbing with a piece of water-of-Ayr stone, moistened with water from time to time.

Emery paper lasts much longer and works more smoothly than emery cloth, very frequently working

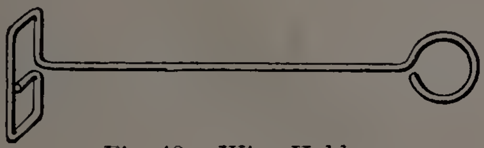


Fig. 48.—Wire Holder.

down to a glossy surface before giving way, and, moreover, the flatness and sharp edges of the work are better preserved with the paper than with the cloth. If the article is now held in a clean rag in the hand, and is then brushed with a soft brush (or a stick covered with one or two thicknesses of woollen cloth) and a little whiting, being afterwards wiped dry on a clean linen rag, it will then be ready for lacquering; or, if desired, the final polish may be imparted by means of a buff stick and a little crocus powder, or any of the numerous polishing pastes and powders.

If a polishing paste is used, the following will be found the best method of using it: Anoint a polishing buff with a little and then rub briskly, and with considerable pressure, upon the surface to be polished, remembering that it is always usual to take the strokes

off lengthwise of the work, which should be the same way as the grain left by the emery papering. This will speedily bring up the surface to a lustrous polish, providing that the article has previously been papered up smooth, and care has been taken to eradicate all the file marks. When the superfluous polishing paste has been cleared off by means of a piece of soft rag, the surface will present a polish very slightly inferior to a burnish in point of brilliancy.

The screw holes will require cleaning out with a piece of pointed wood cut to the requisite size. This is a necessary precaution, otherwise the grease will melt out of the holes when the article is heated and overrun the surface, thus spoiling the lacquering.

Small nuts and screws may be polished by means of a chamois leather which has been dipped in the polishing paste, and is held between the thumb and first finger of the right hand, being quickly rotated over the part to be polished, the superfluous paste being cleaned off by another portion of the leather as soon as the polish appears. Screws will seldom require emery-papering first, unless they are very old and tarnished, as they are generally left tolerably bright from the lathe; but should they need it, the paper may be used in the same manner as the leather.

Although the process just described, in which the file-marks are eradicated by means of emery paper, is very rapid, it is apt, in inexperienced hands, to have a knack of taking off the sharp edges of the work, giving it a slovenly appearance; it is, therefore, usual with the best work to secure a superior style of finish by means of stone-polishing, using grey-stone, blue-stone, and water-of-Ayr stone. This process, although more tedious than the one previously described, imparts that neat and square appearance to the work which, in the eye of a connoisseur, is a sure indication of good workmanship. In order to secure this superior class of finish, instead of using the emery paper to remove the file-marks, the three

qualities of stone mentioned above are employed for the same purpose in the order given. The grey-stone, used first, must be wetted with water, and then worked rapidly across the surface of the metal in circles, until all traces of the file have disappeared, care being taken to prevent it from slipping over the sides or ends of the work so as to damage the sharp edges. This stone is afterwards followed by the blue-stone, which is used in the same manner until it has removed all traces of the coarser stone, the article being finally finished by going over the surface carefully with the water-of-Ayr stone, which is taken straight across the work from side to side, in order to lay the grain, the article being afterwards dried by wiping it on a clean rag. The final polish is imparted by means of metal polishing paste, or, if desired, tripoli and oil may be used instead.

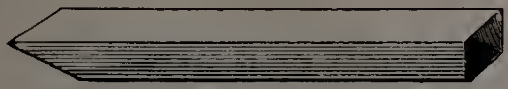


Fig. 49.—Stone with Chamfered End.

A great many workmen file their stones to the form of a chamfer, as shown in Fig. 49, and rub the chamfered portion on the surface of the brass ; a greater pressure is thus brought to bear upon the work, and the task of obliterating the file marks thereby hastened. It will be necessary to wipe the work each time that the stone is changed, and the polisher should be careful not to get any grit on the surface during the latter stages of polishing. When it is wished to finish off the brass in the highest state of perfection cleanliness is the first consideration, and unless all the materials employed are kept distinct from each other and quite free from dust, it will be useless to attempt to get good results.

The work should be lacquered as soon as possible after being polished, as it will soon lose its brilliancy. To prevent the rapid tarnishing as much as possible,

it is usual to wrap the articles in a clean linen cloth until ready for lacquering. The stones above mentioned can be obtained from any dealer in watchmakers' materials. They are sold in slips from 6 in. in length and about 1 in. square. Round and flat buffs are very cheap, and can be readily made by gluing a thin strip of leather on to a narrow piece of wood, as shown in Fig. 50.

Having described the various methods of finishing and preparing the brass work, the process of lacquering may be considered.

An article for lacquering should first be heated by being placed on a stove, or it may be laid on an iron plate and held over a clear charcoal fire or any other source of heat, provided it is protected from the naked flame. Care must be taken not to touch the bright surface with anything that would be likely to stain it. It must now be heated until just too hot for the hand to bear, and yet not sufficiently hot to bubble the lacquer, or, in other words, as near the temperature of boiling water as possible. If the article is allowed to get too hot it will be apt to burn the lacquer, and if it is too cold it will not set. When the brass has been heated to the correct temperature a flat $\frac{3}{4}$-in. brush (which should be clipped and trimmed if necessary) is dipped into the pot containing the lacquer, and scraped against the side to get rid of the excess of lacquer, or it may be wiped across a string stretched over the top of the pot. The brush should now be laid on the work as lightly as possible, with a slightly curved motion at the beginning of the stroke, in order that it may miss the sharp edges, which would otherwise cause too much lacquer to be pressed out of the brush and thus spoil the surface. The brush should be drawn rapidly, but not hurriedly, over the surface of the brass, and lifted off the instant that it reaches the other edge; it must pass over the metal in one steady sweep, and must not go over the same spot a second time while the surface is moist.

When lacquering flat irregular surfaces, the great danger to be avoided is the lacquer collecting around the edges or spreading in irregular quantities. In order to avoid the mishap, some workmen first coat the work with alcohol or very thin lacquer. If the brush is passed a second time over a spot where the lacquer has only partially set, it will result in an unpleasant brown stain; but if the lacquer has been laid on too thin, the article may be heated again and the process repeated with fresh lacquer until a good even body has been laid on, it being simply a matter of practice to lay one coat over another without dragging the previous one off.

Should the surface become spoiled by any mishap

Fig. 50.—Buff.

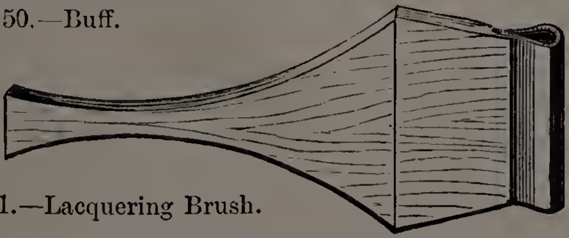


Fig. 51.—Lacquering Brush.

the lacquer may be cleaned off by boiling it in a lye of potash, as before described.

Screws are lacquered by being arranged in rows along a strip of wood. It should be remembered that small thin articles part with a considerable amount of their heat in laying on the lacquer, whereas bulky work remains apparently unaffected. Thus it is necessary to make small articles somewhat hotter than larger articles previous to lacquering.

When the work has been satisfactorily lacquered it should be exposed to a gentle heat for a short time, in order to evaporate the alcohol and harden the lacquer, causing any slight unevenness of the surface to disappear and greatly improve the appearance of the lacquer. A small cooking stove will be

found very useful for heating the work, care being taken that the heat shall never exceed the temperature of boiling water, otherwise the lacquer will be apt to get burned.

In lacquering tolerably broad surfaces a brush the same width as the work should be used; but for very large work, or when there are many screw-holes, an ordinary brush is unsuitable, the best kind of brush for the work being made in the following manner: Cut a strip of wood just a trifle broader than the surface to be lacquered, and shape it to the form of Fig. 51, afterwards cutting a slit with a thick saw through the edge of the wider portion. Now take a strip of clean flannel about 2 in. wide, and of the same length as the width of the wood, and fold it lengthwise; then fold a strip of white nankeen cloth over the flannel, afterwards wedging them both into the slit in the wood with the folded edge outwards, securing them in position by means of some small screws driven through the side of the wood. Before screwing them up tight it will be found advisable to put a piece of straight wire through the bow of the folded cloth, in order that it may be pulled tight, and thus be left smooth and straight. This brush must not be dipped into the lacquer, but should be fed by means of an ordinary brush, with which the lacquer is dabbed on to the nankeen. The woollen cloth holds the lacquer and the nankeen prevents it from flowing too freely, and also presents a smooth surface to the article to be lacquered, preventing any particles of wool from coming in contact with the lacquered surface. With a brush of this kind it is a simple matter to successfully lacquer large surfaces.

It will not, as a rule, be found an economical plan for residents in large towns to make their own lacquer, as it can generally be purchased more cheaply, and nearly always better, than it can be made in small quantities at home; but for the convenience of any readers who may wish to make their own lacquers,

directions are here given for the preparation of a golden lacquer: Take of ground turmeric, $\frac{1}{2}$ oz.; saffron and Spanish annatto, of each $\frac{1}{2}$ drachm. Mix these in a bottle containing 5 oz. of highly rectified spirits of wine, and put it in a warm place, with occasional shaking, for about a week; then strain it through clean, coarse linen into a clean bottle, and add $\frac{3}{4}$ oz. of coarsely powdered seed lac, putting it again in some warm corner, and shaking it frequently the same as before, for about a fortnight, or until the lac has entirely dissolved, when it may be again strained and put in a clean bottle ready for use. It is not wise to use more seed lac than the quantity given above, as it has a tendency to prevent the lacquer from being laid on as evenly as it should.

The optical dead black with which the interiors of lens tubes, etc., are treated is obtained in the following way: For common work a dead black composed of spirit varnish and vegetable black answers very well. Obtain from an oilman a pennyworth of vegetable black, or lampblack, and twopennyworth of ordinary spirit varnish. Mix some of the varnish with methylated spirit, and then add a small quantity of the black, grinding it up with a stick of wood in a small saucer, carefully breaking all the lumps, and adding sufficient black to form a varnish as thick as cream. If a brushful is now tried on a piece of bright brass it can be ascertained whether it is fit to use, as it will dry in a few moments. If it dries shiny, a little more black or spirit must be added; and if it is too thick, a small quantity more spirit and varnish. To apply this varnish to the interior of a lens tube, pour a small quantity inside the tube, and then quickly turn the latter round, in order that it may completely cover the surface, the superfluous black being poured back into the saucer. If properly mixed and applied, this is a splendid dead black, hard, quick drying, and not liable to rub off with a little friction.

A good chemical dead black for the lens cells, stops, etc., may be made in the following manner: Pour ½ oz. of nitric acid into a wide-mouthed bottle, and into this drop as many strips of copper wire as the acid is capable of dissolving, placing the bottle out in the open air in order to avoid the fumes of the gas. When the acid refuses to dissolve any more copper, carefully pick out the remaining portions by means of a forked stick, and then add another ½ oz. of acid and 1½ oz. of clean water. To use this solution hold the article to be blackened on a hook of brass or copper wire and plunge it into the nitric acid solution, which should previously be poured into a saucer or similar suitable receptacle. The article is allowed to remain in this solution for about 15 seconds, and then taken out and held over the flame of a Bunsen burner, or over a charcoal fire, until the colour changes from green to a good dead black. The brass first becomes coated with a thin green film of nitrate of copper, but this changes by prolonged heating to black oxide of copper. When the article is cold the surface black may be brushed off with a blacklead brush. When required, the liquid may be applied to the surface of the brass by means of a camel-hair brush with equal success.

The following are two more chemical dead blacks which may be employed in place of the above, if desired: (1) Make strong solutions respectively of the nitrates of silver and copper, mix them together, and dip the article in this mixture, afterwards heating it over a gas flame until the required degree of dead blackness is obtained. (2) Prepare the following mixture: 1 part of sulphate of iron, 1 part of white arsenic, 12 parts of hydrochloric acid. Immerse the article in this solution until it turns black, then remove, and rinse thoroughly with clean water, afterwards drying it in sawdust and polishing the surface with blacklead.

CHAPTER IV.

IMPROVED MOUNTS FOR SMALL MICROSCOPES.

The purchase of a first-class microscope is not possible, unfortunately, to persons with limited purses. Those who have spare time and sufficient skill may, however, overcome this initial difficulty to a great extent by improving a cheap microscope.

The instrument here dealt with is one of the class sold by the instrument makers as a "Student's Microscope," and is suitable for beginners. In its original form it is in one piece with the base B (Fig. 52) on which it stands vertically. It is sometimes fitted with lens powers of 8, 12, and 16 diameters, the latter of which is probably its limit for non-achromatic lenses. But, of course, the design is suitable for any similar body, however high class. It is quite free from vibration, and admits of the body being raised or lowered, and also swivelled in any direction; and the same remarks apply to the mirror or condenser fitted beneath the stage.

For those who could afterwards get a better instrument, this one need not be discarded, for it will always be found highly useful for viewing the general structure and beauty of small insects, the parts of plants, and for a host of other purposes.

Cut off the mirror portion from the lens portion, and to the latter solder or sweat neatly a brass arm-piece of the form shown, and having a hole in the centre of the end through which the screwed pin N is passed to clamp it in any position to the slotted upright of stand. The stand and upright may be made of brass or of wrought iron, the stand (which is square) having a groove formed in its upper surface into which the foot of the upright is fitted and soldered,

or, better still, brazed. To the arm is fitted and soldered the stem T (Fig. 52) which is a bit of brass tubing, and on the stem is fitted and soldered the stage S, which is of $\frac{1}{16}$-in. brass and is fitted with steel or spring brass clips to hold the slides.

The mirror portion should now be dealt with: Drill a small hole through the base ring B and rivet

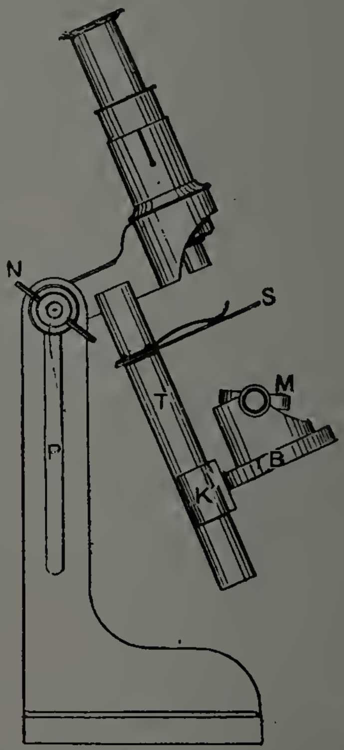


Fig. 52.—Improved Mount for Cheap Microscope.

a short piece of thin brass tube K to it, first interposing a stiffening piece of a sufficient thickness to bring the mirror's centre line true to centre line of lenses. Then solder the whole together neatly, the rivet serving to hold in position. The piece K is then sprung on to the stem T, where, if properly fitted, it will hold the mirror M in whatever position it is placed.

To ensure this, the piece should be cut from a tube

a little smaller in diameter than the stem T and put on a mandrel and well planished on the outside with a hammer-nose or planisher; then it will hold admirably, and may be slipped off or on at will.

The slot P is also very handy for attaching the arm of a condenser or a candle-holder for night work. All the measurements will depend upon the original microscope. The under side of stage, and that portion of its upper surface beyond the glass slides, should be

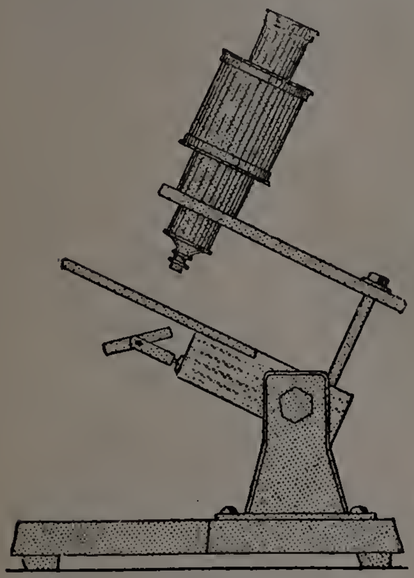


Fig. 53.—Cheap Microscope on New Stand.

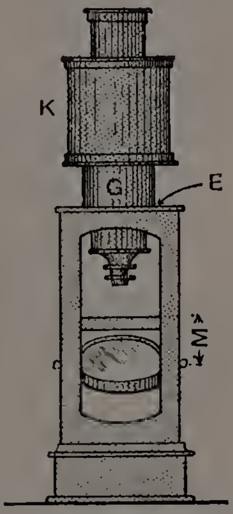


Fig. 54.—Cheap Microscope on its Original Mounting.

coated with a dull black, and if the stand, upright, and arm are painted with a dark enamel paint, the whole thing will have a very neat appearance.

Care must be taken in staining the upright of the stand not to set up cross reflections that would confuse the light on the field, and care must also be exercised to get the field hole in the stage coincident with the axis of the microscope. If the stand is made of brass, it should be cleaned up nicely and bronzed.

Another improved stand for a cheap microscope is illustrated by Fig. 53. For low-power work, this

arrangement will be found extremely useful and convenient. Fig. 54 shows the form of microscope which is to be remounted, and which may be picked up second-hand for a few shillings. The optical parts and the workmanship are generally good, but the principle of construction narrows its field considerably. With such an instrument only small specimens can be placed on the stage, while it is difficult to illuminate some objects, especially opaque specimens; and among other faults is its unsteady upright position. The improved stand, however, offers greater scope in manipulation. The stage will

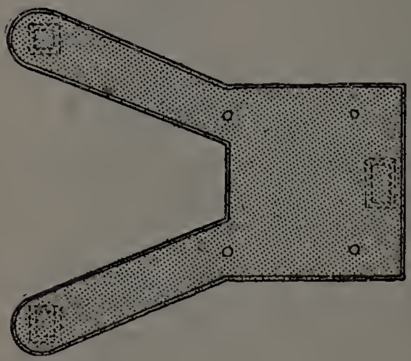


Fig. 55.—Base of Stand.

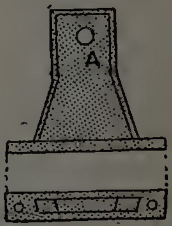


Fig. 56.—Standard.

carry a small tray of water, and is rigid enough to support the operator's hand in dissecting work. There is plenty of room to arrange a large object, and the instrument can be swung round on the rod clear of the stage, so that the preparation can be easily got at by the fingers. Before beginning the work it will be desirable to make a full-size drawing of the various parts. The illustrations herewith are drawn to scale, but can easily be varied to suit requirements.

Castings in iron and brass are good for the purpose, but more easily melted metals will often answer just as well. Solder made of tin and lead is tough and fairly hard, if it contains a fair amount of tin. Zinc

is harder, but brittle, and rather more diffieult to cast. Zine and solder, however, will be found to work very well. The base (Fig. 55) may be east in solder, and being heavy will be found to form a rigid foundation. The top surfaee should be finished level and smooth. The bearings (Fig. 56) are of zine, and bolted to the foot by means of four round-head brass bolts, $\frac{3}{4}$ in. by $\frac{1}{8}$ in. The nuts are sunk into the under surface of the base, by boring a larger hole half through large enough to take the nut. Take eare to get the inner surfaees of the bearings quite flat, parallel to one another and perpendieular to the base,

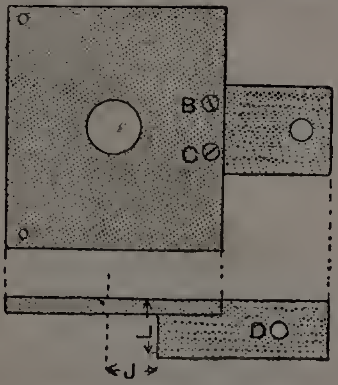


Fig. 57.

Fig. 58.

Figs. 57 and 58.—Stage.

and see that the holes A are quite true. A brass bolt passes through these holes, to earry the wood bloek to whieh the stage, etc., is secured.

A thiek plate of brass is most suitable for the stage (see Figs. 57 and 58), but a plate east in zine will serve the purpose. Square the edges, and true the top level and smooth. Next square up a pieee of beech or other hard wood, and fit it exaet between the bearings. To this bloek the stage is fastened firm and true by the screws B and C. Bore the hole D in the bloek to fit the bolt, and try the block in place. Tighten the nut a little, and tilt the stage. It should now be level, and should hold firmly at any angle.

The plate (Figs. 59 and 60), cast in zinc, is secured

in place as shown in the section (Fig. 61), or soldered, quite firm, to the upright rod, which is fitted firm in the beech block. The plate may be turned round with the rod, or the whole may be slid up and down in the hole in the block; but this motion will seldom be required, so it is advisable to make it a good stiff fit. The hole in which the rod works must be bored quite square, or the instrument will not stand vertical. The old mount will be found to unscrew at E (Fig. 54), and the plate must have a hole F (Figs. 59 and 60) to fit the tube G, which is fitted into F after removing the other parts of the instrument, and soldered square into place. Rejoin the parts, and see that the instru-

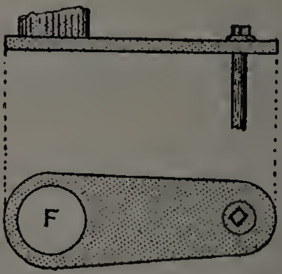


Fig. 59.

Fig. 60.

Figs. 59 and 60.—Supporting Plate of Stand.

ment is fitted true. The axis of the microscope should be quite parallel to the axis of the upright rod.

The mirror (Fig. 62) must be mounted in a semi-circular brass frame, which is fixed by means of the screw H. The pins on which the glass turns are taken from the old mounting, and are screwed through the sides of the frame; or they may be soldered in, and the glass sprung in place. The screw H must be a good fit in the frame. The exact position of the mirror requires careful consideration, especially if it is a concave one. First see that the distances J and K (Figs. 58 and 62) are equal; if not, make them so by packing washers or cutting down the block. Mark a line down the centre of the end of the

block, and on this mark off L equal to M (Fig. 54). The centre of the glass will then be in a line with the axis of the microscope, and at the same distance below the top of the stage as in the old mounting.

Focussing is effected by turning the drum K (Fig. 54), which is screwed inside and fits on a threaded collar fixed to G.

Stage accessories may be added according to fancy. Stage forceps are useful, and are fitted in the holes in the top corners of the stage. If stage springs are used, they must be removable, but a sliding bar is much to be preferred. A sliding bar

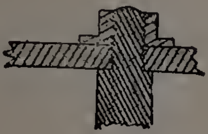


Fig. 61.—Section of Rod and Plate.

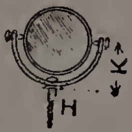


Fig. 62.—Mirror.

may be made of a piece of boxwood $\frac{1}{8}$ in. thick by $\frac{3}{4}$ in. wide, and about 1 in. longer than the stage is wide. Glue a piece of cork $\frac{1}{8}$ in. thick across each end, and trim it so that when laid across the stage the pieces of cork hold the edges, enabling it to be slid up and down and to hold in any position.

When complete, clean up all the parts, and give the stand two coats of black japan, allowing the first coat plenty of time to dry before applying the second. Touch up any bright places inside the instrument with lampblack ground in french polish thinned with methylated spirit, and clean the lenses. The brass-work may be relacquered, if necessary ; but this is a process requiring great care (see Chapter III.).

CHAPTER V.

MICROSCOPISTS' LAMPS AND BULL'S-EYE CON DENSERS.

Lamps for use in microscopy are of special shape, and one that can easily be made by the homeworker is

Fig. 63.—Microscopist's Lamp.

shown by Fig. 63. The advantages of the lamp are : (1) That instead of the ordinary lamp chimney, a chimney of tin-plate is substituted, in which is an

ordinary 3 in. by 1 in. glass slip, or a slip of tinted glass of the same size ; (2) the glass slip can easily be replaced, costing 4d. per dozen ; (3) the glass slips do not break so easily with the heat as do glass chimneys ; (4) the lamp is so low that, by tilting the microscope a little, direct light may be got from the lamp without reflecting the light by mirror.

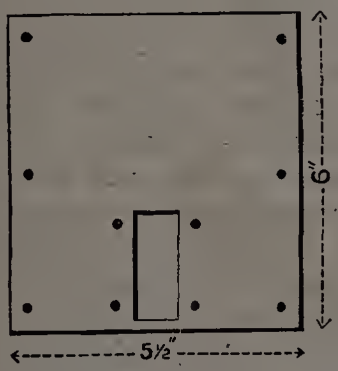


Fig. 64.—Tin-plate to Fit Over Lamp Glass.

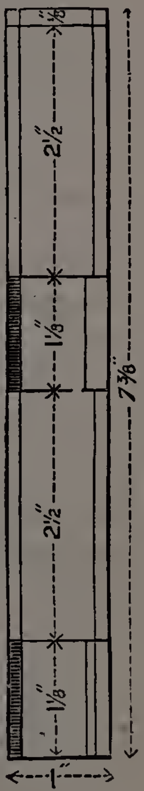


Fig. 65.—Template for Box.

The lamp body should be bought ; its cost should not exceed 6d. or so. The wick stands about 3 in. from the table. Get a piece of tin-plate, 6 in. by $5\frac{1}{2}$ in. (Fig. 64), and mark out (beginning $\frac{3}{8}$ in. from the side) by means of rule and steel point an oblong measuring $2\frac{1}{2}$ in. by $1\frac{1}{4}$ in. ; then, by means of a cutting chisel, cut the piece out. Next prepare a strip of tin-plate $7\frac{3}{8}$ in. by 1 in. (Fig. 65). Rule right across it four lines, at $1\frac{1}{8}$ in., then at $2\frac{1}{2}$ in. from last, then at $1\frac{1}{8}$ in.

and again at $2\frac{1}{2}$ in. Then rule right along one edge $\frac{1}{4}$ in. from side, and on the other side $\frac{1}{8}$ in. and at $\frac{1}{4}$ in., as shown. Bend the box into shape, after snipping at each of the marks $\frac{1}{4}$ in. on each side. This will leave $\frac{1}{8}$ in. over at end, which requires soldering. Snip the box at top and bottom as shown (Fig. 65), so that the box will accommodate itself to the round shade. When this is done, push the box through the hole in the large sheet, bend up the $\frac{1}{4}$ in. as a flange, bore two holes on each side of the box through both sheet and flange, and rivet with copper rivets. Now bend the sheet on a round article, allowing about $\frac{1}{4}$ in. to wrap over, and bore holes and rivet. The chimney will now be $1\frac{3}{4}$ in. in diameter, and this will suit most lamps.

It will be found that the box will be thrown a little out of shape by bending the chimney into the round form, but this can easily be remedied by a few touches of the pliers. Now bend the top piece outwards $\frac{1}{4}$ in. as marked, the bottom piece outwards $\frac{1}{4}$ in., then inwards again for $\frac{1}{8}$ in., and the side pieces $\frac{1}{8}$ in. inwards, as shown in Fig. 66. The box will then appear as in Fig. 66, and will allow of the glass slipping in from above, being held there by the side flanges.

All that remains is the making of the shade. This shade prevents the light of the lamp coming to the unoccupied eye. Cut out a piece of tin-plate, $4\frac{1}{8}$ in. by $1\frac{1}{4}$ in., shaped as in Fig. 67; this will allow $1\frac{1}{8}$ in. for top and $1\frac{1}{2}$ in. for each side. Snip at each mark to $\frac{1}{4}$ in., then bend into shape, and bend inwards each of the pieces snipped $\frac{1}{4}$ in.; this will then allow the shade to rest on the glass slip, as shown in Fig. 63. The tin shade, being bright, is a good reflector, and a great deal of the light lost in every direction with a glass chimney is now reflected and sent out in one direction; besides this, by using direct light from the lamp, a good light is got for high powers or for rather opaque objects.

Approximately, the lamp will cost: Lamp body, 6½d.; one sheet double-crown tin-plate, 5d.; 1 oz. of copper rivets, 2d.; one glass slip, say, ½d. Total, say, 1s. 2d.

A more usual shape of lamp is illustrated by Fig. 68. This is useful both when performing dissections and for illuminating the stage of the microscope, with or without a condenser. The base F is of iron or brass, and carries the vertical rod G, on which the lamp can be adjusted vertically. The lamp is shaded by a paper or porcelain shade, also adjustable for height on the rod.

Fig. 66.—Box Bent into Shape.

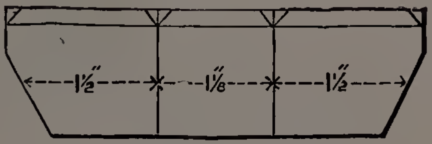


Fig. 67.—Hood or Shade for Box.

One of the most useful accessories to the microscope, and one without which no outfit is complete, is the bull's-eye condenser for the illumination of opaque objects and those mounted in dark cells. The lens itself is plano-convex with a diameter of about 1½ in. or 1¾ in., and a focus of about 3 in. This must be mounted on a good solid base, in such a manner that it can be turned any way, to any angle or plane, in order to concentrate the light of the lamp on to the opaque object viewed.

Referring to Fig. 69, the base A can be turned out of a piece of hard wood, hollowed underneath, and filled with lead B, to give sufficient weight and solidity to the stand. (If a lathe is not available, cut the base

out to an octagonal shape, from two pieces of oak.) Into the base fix a piece of brass bar or tube, $\frac{1}{4}$ in. in diameter, on the top of which solder a brass ball, $\frac{1}{2}$ in. in diameter. Next take two pieces of brass C, $\frac{1}{16}$ in. thick, $2\frac{1}{2}$ in. long, and $\frac{3}{4}$ in. broad.

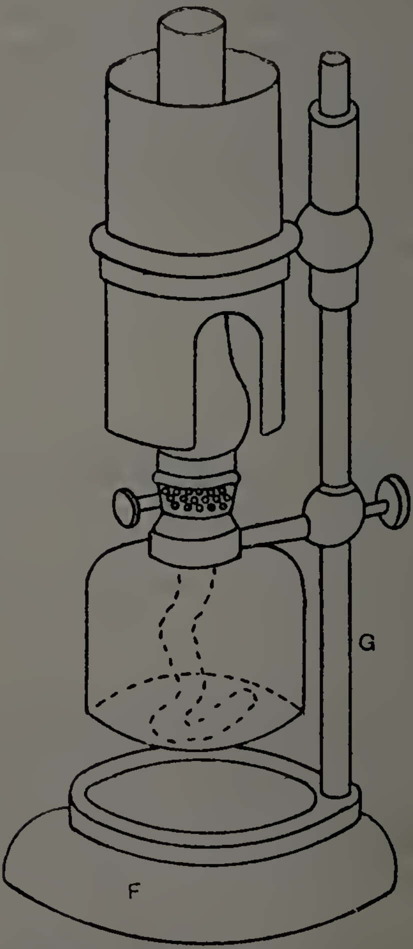


Fig. 68.—Microscopist's Lamp.

Equidistant from each end drill a hole about $\frac{1}{8}$ in., and countersink one edge of each with a larger drill to fit the curve of the balls. Clamp the two parts C together with two screws as shown, the balls being placed at the top and bottom in the recesses drilled

to take them. In the top ball is soldered a piece of brass bar connecting it with the frame of the lens.

The frame to hold the lens is made with two brass or hardwood rings as shown separately at D, one ring being left flat, and the top one having its bottom

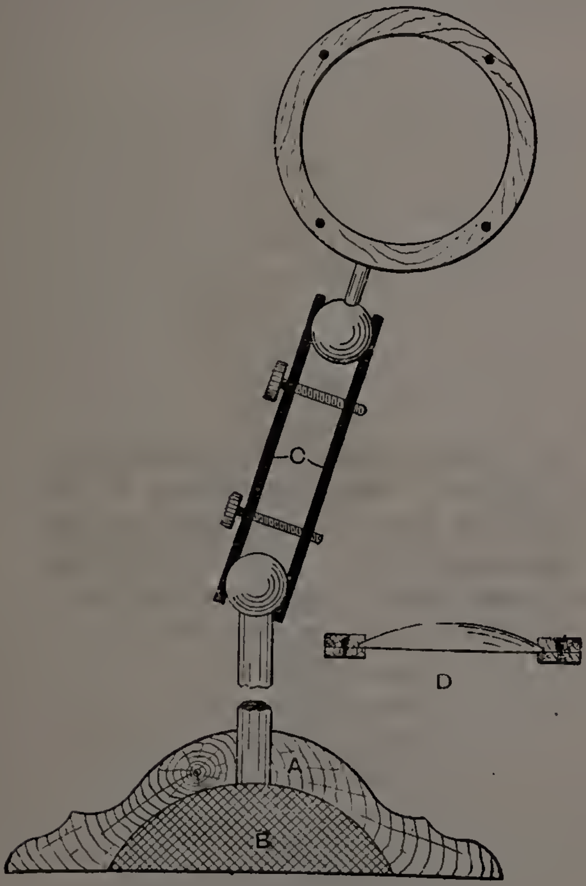


Fig. 69.—Bull's-eye Condenser.

inside edge bevelled off to hold the lens in its place The two rings are held together with four small screws.

When used with daylight, or for converging rays from a lamp, the plane side of the lens should be turned towards the object, but for concentrating light on to the concave mirror of the microscope the plane side should then be turned towards the lamp.

CHAPTER VI.

MICROMETERS AND THE MEASUREMENT OF MICROSCOPIC OBJECTS.

USERS of microscopes are sometimes puzzled to understand the terms used with reference to the lenses of their instruments. For instance, it is frequently asked: When magnification is stated at so many diameters, does it mean that the dimensions of an object are increased to that extent? In theory that is what is meant; the measure of the magnification is the ratio of the diameter of the image to that of the object, both being at the distance of most distinct vision. In practice, however, the magnifying power is generally less than it is stated to be; though it may sometimes be greater. In the process of manufacture, the lens-grinder may obtain perfect lenses, which, in combination, may be in agreement as far as the essentials of spherical and chromatic aberration are concerned, but there may be a loss of magnifying power. In a compound microscope, the magnifying power is the product of the magnifying powers of the object-glass and the eyepiece. If the first magnifies twenty times, and the other ten times, the total magnifying power should be 200. There may be a mechanical loss on this, but this should not be considerable.

One method of making micrometric measurements is to use a small glass plate, on which a series of fine lines are drawn at a distance of 1/10 mm. or 1/100 mm. from each other. This is placed in front of the object-glass, and the rays from the eyepiece are received on a piece of glass inclined at an angle of 45 degrees. The eye is placed above this to view the image of the micrometer lines, formed by reflection on a screen

placed horizontally below the glass. On this screen is a scale divided into millimetres. By counting the number of divisions of this scale corresponding to a certain number of lines of the image, the magnifying power is obtained. Now assuming that the lines of the micrometer are 1/100 mm. apart, if the image measures 45 mm. on the scale, and contains fifteen lines of the micrometer, the exact size of the object will be $\frac{15}{100}$ mm., and the magnification will be $45 \div 15/100 = 300$.

The stage micrometer is a glass slider, and is in the usual place for the object; it is divided by lines 1/100 in. and 1/1000 in. apart. This, being placed upon the stage, and having its image drawn on a sheet of paper at a distance of 10 in. from the eye, the magnifying power of the microscope is determined by comparing the sketch with an ordinary scale, ruled to 1/10 in. Thus, if three divisions at 1/1000 in. apart, occupy when marked on the paper 6/10 in., the magnifying power would be 200.

The most accurate means of measuring the dimensions of an object is afforded by the eyepiece micrometer. Errors in the accuracy of the divisions of the stage micrometer are multiplied by the whole power of the microscope, but in the eyepiece micrometer they are multiplied by the magnifying power of the eyeglass only. The most perfect form, the cobweb micrometer, consists of two parallel threads passing across the diaphragm of the eyepiece; one being fixed, the other is moved across the field by means of a screw with 100 threads to the inch, its head being divided into 100 equal parts. When the screw is turned, the divisions on the head pass a fixed index. A portion of the aperture of the diaphragm is cut off by a comb at right angles to the threads. The teeth of this comb are also 1/100 in. apart. To measure an object, one end must be brought into contact with the fixed thread, the other thread being moved until

it reaches the opposite end of the object. The number of the teeth in the comb between the two threads will indicate the number of complete turns of the screw, and the number on the circular head will show the number of 1/100ths of a turn. The value of these indications is determined by the stage micrometer. Thus, if $3\frac{5}{100}$ turns be required to move the thread over the magnified image of the space between the two adjacent lines on the stage micrometer, ruled 1/1000 in. apart, a complete turn of the screw will indicate an actual dimension in the object of 1/3050 in., and a motion of one of the divisions on the circular head past the index will denote a distance of 1/305000 in.

A cheaper form of eyepiece micrometer consists of a thin plate of glass divided like the stage micrometer, but set in a frame. When placed in the eyepiece, in the focus of the eyeglass, it can be moved across the field of view by means of a milled-head screw. The actual value is determined by the stage micrometer, and it is necessary to take several measurements on different parts to eliminate error, When the magnifying power has been determined, the size of the image divided by the magnifying power gives the size of the object. In this way the diameters of all microscopic objects are determined.

Another question frequently asked is: What is the relationship between the eyepiece and the object-glass of a microscope? The magnification produced by the object-glass depends upon its focal length and its distance from the object, which must exceed the focal length. The magnification produced by the eyepiece depends upon its focal length and on the distance of most distinct vision by the eye of the observer. Suppose, for example, that the focal length of the object-glass is 1/5 in., and that of the eyepiece $\frac{3}{4}$ in. If the object is placed 1/250 in. beyond the principal focus, or 50/250 in. from the centre of the lens, a real, inverted image will be

formed at a distance of $10\frac{1}{5}$ in. from the lens on the other side of it. The magnification of the object-glass will be 50. Then for an observer whose distance of most distinct vision is 10 in., the eyepiece must be placed at a distance of 30/43 in. behind the image, and the magnification produced by the eyepiece will be $14\frac{1}{3}$, the entire magnification being 50 multiplied by $14\frac{1}{3} = 716\frac{2}{3}$. This determines

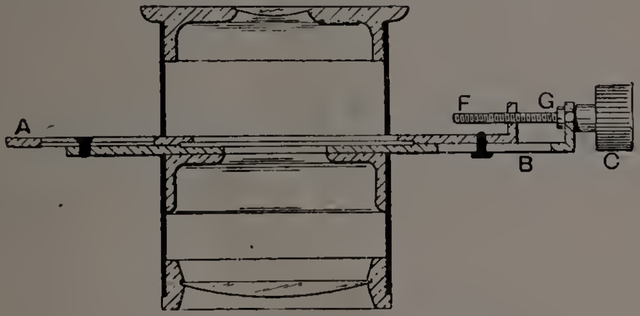


Fig. 70.—Section of Micrometer.

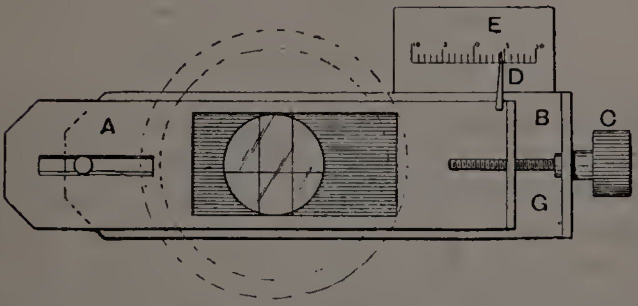


Fig. 71.—Plan of Micrometer with Eyepiece Dotted.

the distance between the object-glass and its eyepiece, or the length of the instrument, which is $10\frac{1}{5} + \frac{30}{43} = 10\,\frac{193}{215}$ in., or very nearly 11 in.

With the same object-glass and eyepiece other degrees of magnification may be obtained. The distance between the object-glass and the eyepiece being shortened or lengthened, the place of the image approaches the object-glass or recedes from

it as the object is moved further off or brought nearer. Thus by the eyepiece tube sliding along the tube to which the objective is attached, variations may be made in the magnifying power. Finally, distinctness of vision depends entirely on the quality of the lenses, a good objective always giving a clear field with distinctness of detail.

It is possible for the reader to construct with but a few tools a simple micrometer, which will be found a very useful accessory to the microscope.

The micrometer about to be described consists of two parts—first, the small slide fitting into the eyepiece, with which the length or breadth of an object is gauged by two parallel lines marked on glasses, moving one above the other. This sliding

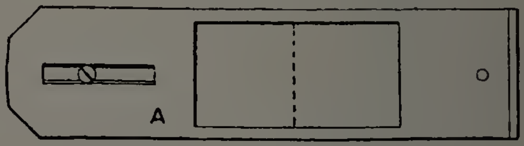


Fig. 72.—Top Sliding Plate.

motion is worked by the milled head C and screw F (Figs. 70 and 71). The second part is an ordinary stage micrometer, ruled to the one-hundredth and one-thousandth part of an inch, and the one-tenth and one-hundredth part of a millimetre. As it is quite impossible for anyone, except with proper appliances, to rule these lines, which are almost invisible on the glass, the slide must be bought. Beck and other makers and dealers supply them. The use of this slide is to compare the measurement of the object taken by the lines in the eyepiece with the actual fractional parts of the inch or millimetre, as shown by the magnified image of the ruled stage slide. The real size of the object can then be arrived at even though it be less than one-thousandth part of an inch long.

The eyepiece micrometer is, however, fitted with

an index and pointer D and E (Fig. 71), which will do away with the necessity of removing the object to apply the stage measure each time the size needs to be taken. When this index has been adjusted to the eyepiece and objective it will render the micrometer complete, but the stage rule is required for the adjusting.

The eyepiece micrometer is made of two thin plates of brass about $\frac{1}{32}$ in. thick, cut out to exact size and shape, as in Figs. 72 and 73 (Figs. 70 to 73 are full size). The bottom plate B (Fig. 73) has a circular hole cut to the same size as the stop of the eyepiece used. The upper plate A (Figs. 70 to 72) has an oblong opening. Over these openings the thin glass with

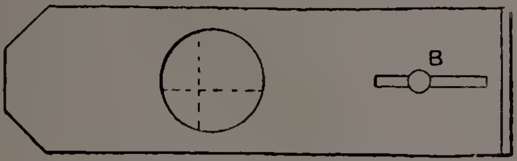


Fig. 73.—Bottom Sliding Plate.

the fine line on each is fixed, the plates being slightly sunk to allow the glass to fit in flush with the surface.

The glass is fitted on the top of the plate B and on the bottom of the plate A, so that they will slide one just above the other, as closely as possible. The plates are made to slide by means of the slot cut in each, the small screws, as shown, holding them together. The screw F works freely through the plate B, and screws into the top plate. The small collar G holds it in its place. If preferable, G can be substituted for a small spiral spring; this will give the plates a very smooth motion.

Cut two pieces of thin micro-cover glass to fit the plates, into which they are fixed by a little wax or cement. Previous to fixing, a very faint line or scratch must be ruled with a diamond. For ruling these lines, which are much exaggerated in thickness in the figures, it will be found best to embed the

glasses in wax to hold them firm, and then, with the aid of a flat rule, mark the lines with an ordinary glazier's diamond. Absolutely no pressure must be used, otherwise the thin glass will either be cut right through or marked too deeply. The faintest possible line is quite sufficient.

The micrometer, when complete, is made to fit into the eyepiece, resting on the stop, two slits being cut in the tube to take it. If fitted properly, the slide will hold in firmly without anything else.

A small pointer D must be fixed on the upper plate. The index card E is held in position by a spring on the bottom.

To rule the index, proceed as follows:—Place the purchased ruled slide on the stage, and bring it to focus. Screw the two lines in the eyepiece till they coincide, and move the stage slide till one of its rulings is in the same line of sight with the eyepiece lines. Then mark the position of the pointer on the card; this will be the zero point. The other divisions of the index are marked off on the right and left of the zero point by screwing the line on the eyepiece to coincide with the lines of the stage micrometer.

On one side of zero inches should be marked, and on the other side millimetres. Every different objective or eyepiece used will require to have a different index-card made. To avoid confusion, it is advisable to write on the back of the index the eyepiece and objective for which it is to be used.

If the microscope has a draw-tube to it, it will be as well to take all the measurements with the body tube pulled out to the standard length of 10 in.

CHAPTER VII.

TURNTABLES FOR RINGING SLIDES.

One of the most necessary appliances in the production of neat-looking slides is a turntable. In mounting microscope objects on glass slides, circular cover glasses are now almost wholly used, except for very large objects which are of greater length than the width of the slip. To cement these neatly some appliance is needed to whirl the slip rapidly while a brush full of cement is held at the edge of the circle. Turntables are made in various styles by the microscope manufacturers, but are mostly of metal, and arranged so that the table must be revolved by hand, the weight of the table and the nice adjustment of the bearings causing it to turn steadily and long enough for the purpose. The home-made table is generally of wood and is thus not heavy enough to turn for a sufficiently long time; therefore, some clockwork or other arrangement must be added to supply the turning power. Fig. 74 is a side elevation, Fig. 75 a plan, and Fig. 76 a view of the interior of a turntable made from a cigar-box, the turning apparatus having been devised from the cog-wheels of an old egg-beater. Similar cog-wheels can be picked up almost anywhere.

Fig. 74 gives a side view of the table, and shows how the box is strengthened by nailing pieces of wood with bevelled edges along the bottom. Fig. 76 gives a view of the end with the end piece removed, showing the internal arrangements and how the cog-wheels are arranged to give the motion to the table. The bearings are all of wood, except those for the upright shaft which carries the table on its end. These are made of thin pieces of brass held in place on the wood blocks, as shown.

The illustrations show how the wheels are arranged. The main shaft extends through one side, and is squared off to admit of a small crank being placed on the end. The short shaft turning at right angles with it extends up through the top, and has a small shoulder turned on it just above the level of the top. This shoulder supports a brass seat, on which rests the wooden table. The shaft has a screw cut on the end, and extends up into the wooden table,

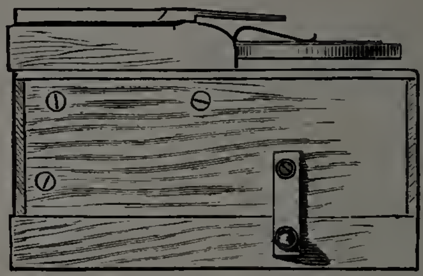


Fig. 74.

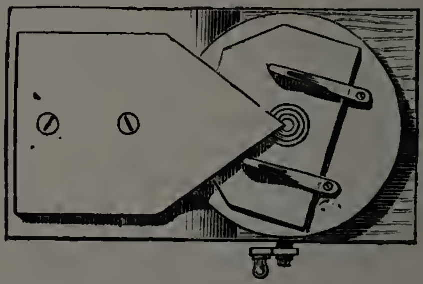


Fig. 75.

Figs. 74 and 75.—Side View and Plan of Turntable.

but not through its whole thickness. A large hole is sunk in the centre of the table from the top, extending half-way through. In this hole is placed a brass nut, which screws on to the upright shaft, and holds the table firmly in place. Fig. 75 shows the top of the arrangement.

The table is about 4 in. in diameter and about $\frac{1}{2}$ in. thick. It is set on the top of the box at one end, and a rest is made for the hand a little higher than the table, and extending out over it, as shown;

Brass spring clips are fastened on the top to hold the slides in place; and pins may also be inserted to assist in centering the slide, although these will be of but little advantage in a simple affair of this kind.

The only guide necessary, and the best one to use with this arrangement, is to draw circles on a piece of cardboard, which is fastened under the clips, as shown in the illustration. The largest circle with which to centre the slide endwise should be 3 in. in diameter, and the next one smaller, 1 in. in diameter, or just the width of the slip. Other circles, each $\frac{1}{8}$ in. smaller than the other, may be drawn as shown,

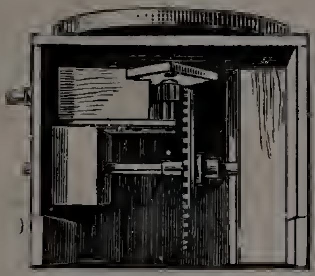


Fig. 76.—Inside View of Turntable.

to assist in centering the slip. With this table slides can be cemented in as good a manner as it is possible to do with any turntable. The motion given by the crank is so positive that it can be used for many purposes for which the ordinary table is almost useless. The principal of these is the removing of hard balsam from the mounts. After the balsam has thoroughly dried, centre the slip on the table, and hold a small knife or other sharp instrument as one would hold a chisel. Then give the table a good turning, and the balsam will fly, and can be turned off so neatly that little cleaning is necessary afterwards.

The Shadbolt turntable, of which there are now several kinds, can be bought for a few shillings, but it can easily be made by a metal turner. Fig. 77

is a side elevation and Fig. 78 is a plan of a home-made one. It consists essentially of a brass table A, the central pivot of which revolves in a socket bearing, also of brass. A milled collar, turned by the forefinger, revolves the table, which is provided

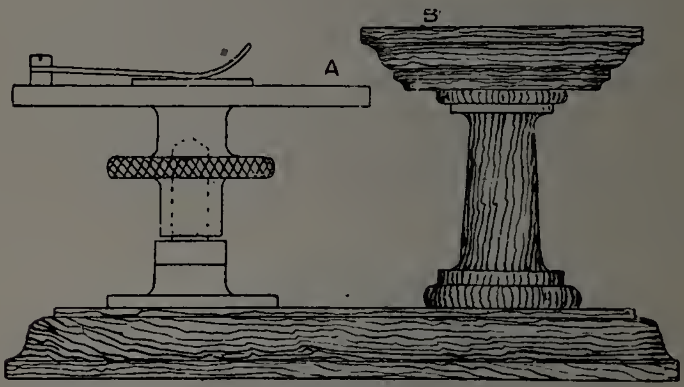


Fig. 77.

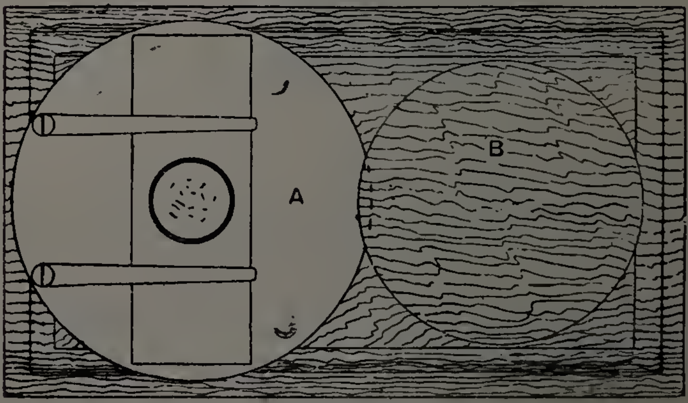


Fig. 78.

Figs. 77 and 78.—Side Elevation and Plan of Shadbolt Turntable.

with two spring clips for holding the glass slips firmly in place. The slip being duly centred, the milled collar is turned by the forefinger of the left hand, and a camel-hair brush charged with cement held perpendicularly over that part of the slide on which it is desired to make the ring. The right hand, which holds the brush, is rested and steadied

on a block of wood or pillar B (Figs. 77 and 78). Many turntables have been invented with a device for setting the slides centrally at once, and thus saving time and trouble, and are known as self-centering tables. One device of this nature is described below.

Microscopists have frequently experienced the need of a simple automatic turntable. In the instrument described below, the manipulator has the advantage of being able to use both hands for his work, while the slide to be operated upon may be kept rotating at a uniform, easily regulated speed.

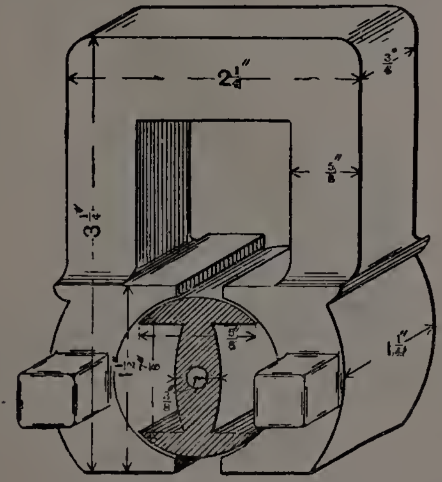


Fig. 79.—Electric Motor for Electrical Turntable.

The turntable consists of a small electric motor with a vertical spindle, and a brass plate for automatically centering and fixing the slide. Castings for the motor can be obtained from many dealers in electrical goods at a small cost.

The dimensions given in Fig. 79 are from an actual instrument. The following details should be observed: (*a*) Wind fields with $\frac{1}{4}$ lb. and armature with $1\frac{1}{2}$ oz. of No. 20 S.W.G. double-cotton-covered wire: (*b*) The brass pieces A and B (Fig. 80) should be arranged for equalising wear in the following manner: The

hole in B should be slightly conical, the armature spindle being correspondingly taper; A must have a fine threaded screw with conical end, which carries the armature spindle upon a centre-hole at C. (*c*) The motor, when completed, should be mounted upon a wooden stand, a central hole being made in the latter to admit a screwdriver for adjusting the screw. Connections should be carried to two binding screws (not shown) with a switch (also not shown) for turning the current off and on. (*d*) The top of the armature

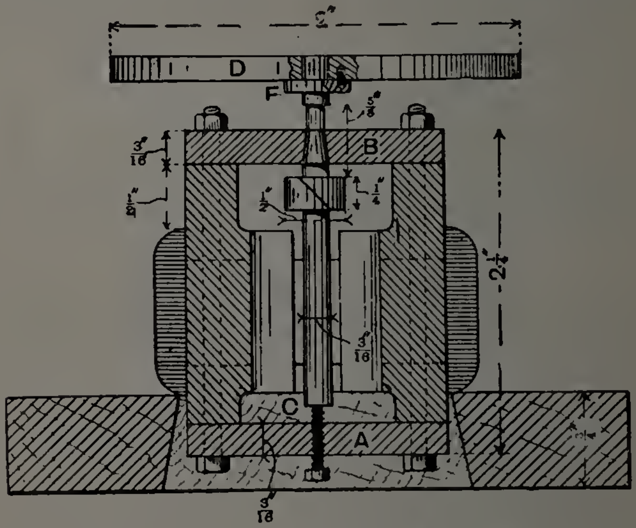


Fig. 80.—Elevation of Electric Motor and Disc.

spindle should be threaded to carry a small brass flange F (Fig. 80) with a pin.

The turntable proper consists of a brass disc 3$\frac{1}{8}$ in. diameter, $\frac{3}{16}$ in. thick, turned perfectly plane and true in the lathe. Holes are drilled in the centre to admit the top of the armature spindle, and three $\frac{1}{8}$-in, holes are drilled and tapped as shown in Fig. 81. Three pieces of brass (J, K, L) $\frac{1}{8}$ in. thick must then be cut as shown in Fig. 82, and, after being filed smooth, they should be fixed to the large disc (D, Fig. 80) with screws, as shown in Fig. 82.

The turntable is now complete. To use it, take

a 3-in. by 1-in. glass slide, and drop it between the jaws J and L, and push the wedge-shaped piece K (Fig. 82) until the slide is grasped centrically. Place the whole on the flange of the armature spindle, connect up a single bichromate bottle battery to

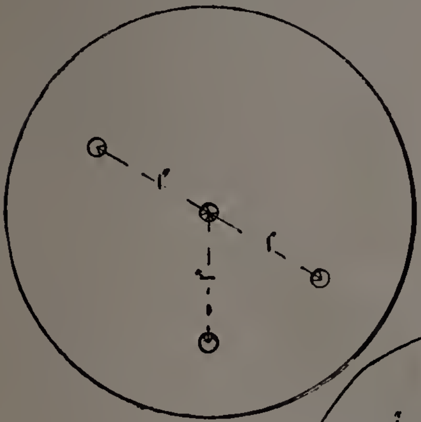


Fig. 81.—Plan of Disc.

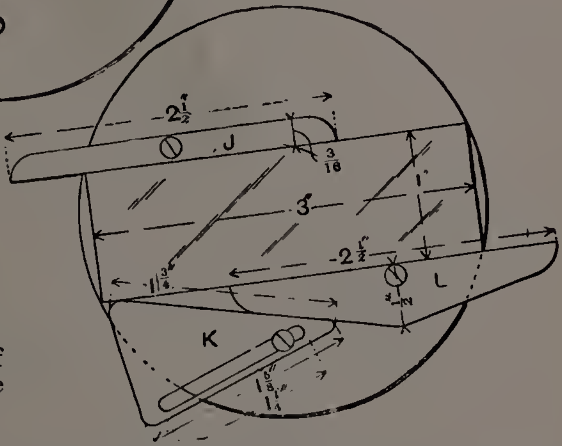


Fig. 82.—Plan of Disc with Slide in Position.

the binding screws, start the disc, and it will continue rotating until the current is turned off.

With an instrument constructed as described above, the manufacture of microscopic slides is much facilitated; cement circles of any diameter or thickness may be applied to the glasses with an accuracy otherwise not easily attainable, and all the minor details of slide making become a pleasure.

CHAPTER VIII.

APPLIANCES FOR COLLECTING OBJECTS.

ALTHOUGH the microscopist gathers his treasures from every source in earth, air, and water, one is often in doubt when beginning so wide a study to know where to find many living forms described

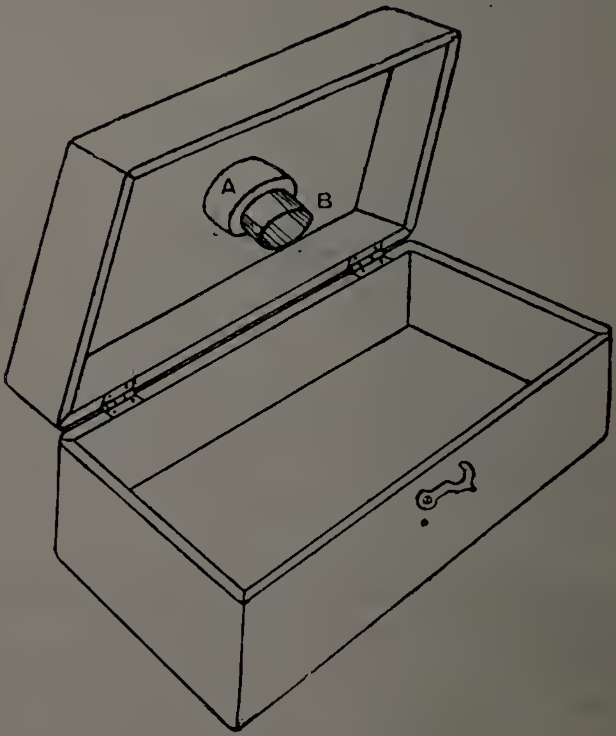


Fig. 83.—Large Collecting Box.

and figured in books, and how to capture them when their habitat is known. The equipment of the microscopist, too, will vary with the nature of his quest. To some extent, at least, he must be an entomologist, a botanist, a geologist, and an

anatomist, and employ the aids and instruments required in the pursuit of those branches of science. For the capture of many insects there are necessary the gauze net, the sweeping net, the pond stick, and some pill-boxes. It is not necessary to describe these very common articles, whose forms must be familiar to most, but rather their mode of use.

On a spring or summer day the microscopist goes

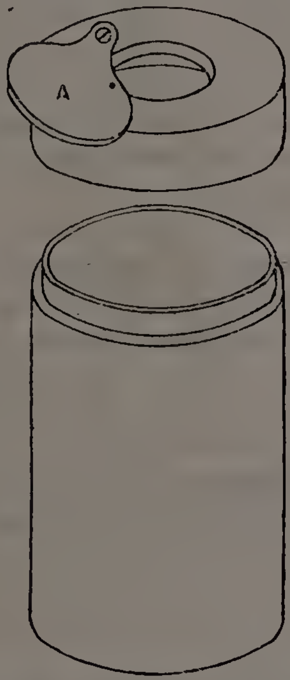


Fig. 84.—Small Collecting Box.

out provided with pill-boxes and small glass bottles or corked specimen tubes. The pill-boxes cost from 1s. 6d. to 2s. 6d. a gross, and the specimen tubes from 6s. to 10s. a gross, according to their size. Also he carries a box or a couple of boxes like Fig. 83, perhaps three or four like Fig. 84, and a strong canvas sweeping net. He sweeps the undergrowth of the hedges by dragging the net along, mouth upwards, through the herbage, beating off the insects which swarm therein into the net. A stick will be used for

beating the hedge above the net, but large numbers of creatures will also be shaken into it by the act of sweeping alone. After going along a few yards in this fashion the contents of the net are examined to see if they are worth preserving. The readiest way is to turn the net mouth downwards in the centre of the roadway, and pick up as rapidly as possible such of the objects as may be wanted, capturing the quick runners first. Very soon so many will have been captured that the greater number will be allowed to go free. Spiders, and after these insect larvæ of all sorts and sizes, will be the most abundant; then small flies and the smaller beetles, but scarcely any of the swift-flying insects.

The pill-boxes are suitable only for taking one swift-running or winged object each. While putting a second in, the previous occupant will probably get out, hence the advantage of the boxes shown in Figs. 83 and 84. These are simple articles which almost anyone can make, Fig. 83 being mitred or dovetailed together, and Fig. 84 being turned in the lathe. In each instance the covers are lifted only to take out the insects, never to put them in. The boxes being kept closed, the brass cover A (Fig. 84), pivoted on a screw, is slid to one side, the objects dropped through the hole, and the cover A slid back immediately.

Fig. 83 shows a box which will contain a large number of captives. It has a sliding brass cover precisely like A in Fig. 84. There is no risk of any previous captives escaping on the momentary opening of the slide for dropping in another captive, because the descending tube B of brass or tin, driven into the cover, bars the way. The piece A is merely a thickness boss glued within the cover to steady the brass tube B, the wood in the cover being scarcely thick enough to hold the tube. The occupants can all be killed by a few drops of chloroform introduced in the same fashion. It is necessary to carry a

little bottle of chloroform, and to keep the box permeated with its odour, and so kill or stupefy the insects as they are put in; otherwise the strong will devour the weak. The best form of box for regular hunting is that shown in Fig. 83, as being most roomy. But that shown by Fig. 84 is also handy for carrying in the pocket when out walking without the ostensible purpose of insect hunting. Very seldom does one go into the country without coming across a stray object or two which is well worth preservation, or objects which at another time might be found only after much troublesome search. It is then annoying to lose a prize for want of a box or bottle. Sizes of boxes may vary much; the large boxes may be about 6 in. by 4 in. by 3 in.; and the small ones $2\frac{1}{4}$ in. diameter by 3 in. deep.

If butterflies are captured with the gauze net they must be put each in separate pill-boxes to avoid intermingling of the scales of different species, and they ought to be killed as they are put in, to prevent them from beating the dust from their wings. The most showy butterflies are no more to the microscopist than the plainer kinds; all alike have gorgeous scaly coverings.

Swift-running beetles should be taken, for beetles' jaws are most marvellous structures, as well worthy of study as the wonderful markings on butterfly scales. Two-winged flies, and insects which often look like flies but are not so in reality, will hover and dart about the collector; capture some of these and determine their species on the return home.

A pond of dirty water, very stagnant, slimy, and unattractive, contains countless forms of microscopic life. Partly fill the little corked bottles and specimen tubes with water taken from different parts of the pond, especially skimming the surface, the margins, and the weeds. Pull out weeds growing by the margins of brooks and carefully overhaul

them. Here are numerous insect larvæ which are always interesting. Flowers can be taken home and there dissected and examined at leisure. Probably there will not be time to examine all these things at once, so put a portion aside in a preservative fluid, in which they will keep unchanged for an unlimited time, even till the next winter. The fluid (Hauntch's) is composed of alcohol, 3 parts; water, 2 parts; and glycerine; on first mixing, the glycerine sinks to the bottom, but after standing

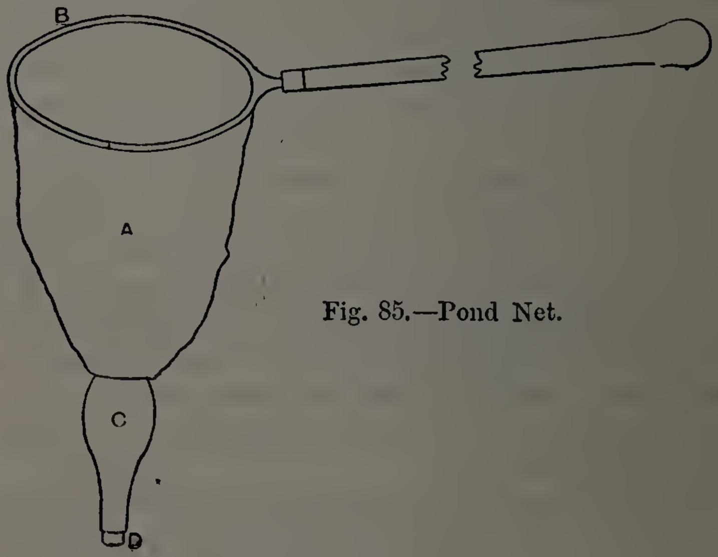


Fig. 85.—Pond Net.

for about a couple of days complete union of the fluids takes place. It should be made in quantity, being a most useful mixture, suitable for both animal and vegetable substances.

Large quantities of insects and insect larvæ can be readily collected by beating the branches of trees and shrubs with a stick, the spoil falling into an inverted umbrella placed beneath upon the ground. The under sides of leaves, the corollæ of flowers, the turf, and the mould will all furnish their quota of objects.

For pond-hunting, a cheap and efficient pond net

can be easily rigged up. Fig. 85 illustrates a useful kind of net. The net A, of holland, is rove on its iron ring B at the mouth, and has a common lamp chimney C at the small end, the bottom of the latter (the top when actually performing its legitimate function) being closed with a cork D. On lifting the net from the pond all the water, except that which is in the glass chimney, drains out through the

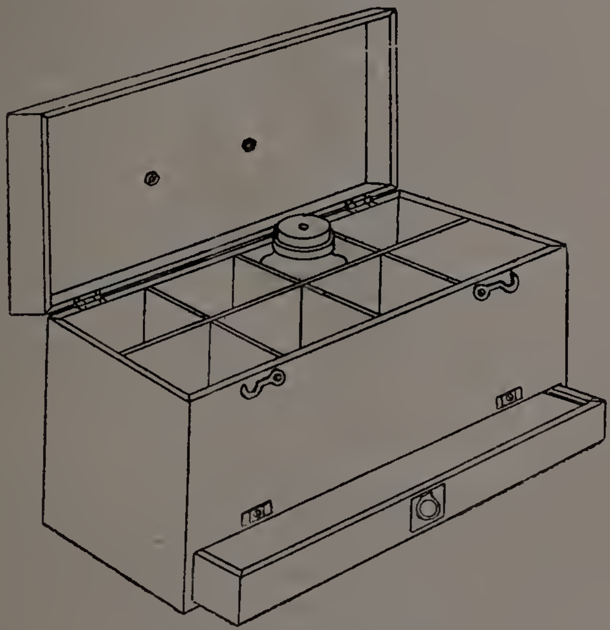


Fig. 86.—Box for Bottles.

holland, but all the minute organisms pass down into the chimney. Holding this up to the light, the smallest objects are clearly seen, being magnified by the body of water in the glass. If there is not anything worth keeping, withdraw the cork and let the water escape, and cast the net again. If there are good captures, hold the glass over the mouth of a wide-necked bottle so that the contents will drop into the bottle.

When using the net, cast it mouth downwards into the water, shake it among the weeds, and turn

it sharply round to bring the mouth uppermost, when the current induced will sweep the tiny inhabitants into the mouth. Several bottles will be wanted, and these may be carried in an open box having a handle arching over the top. But they will be preferably contained in a more completely closed box, like Fig. 86. This has six or eight holes for 4-oz. or 6-oz. bottles, one of which is shown in place. The bottles are closed with perforated corks, and must not be quite filled with water. The drawer at the bottom, shown partly open, is lined with glass cemented in with very thin white lead, and is used to carry home aquatic weeds, or a newt, or frog, or anything too large for the bottles. It is closed with a closely-fitting sheet of stout glass, which rests upon the top edges of the glass slips which line the sides. A ring is let into the drawer in front, and a couple of buttons keep it closed when carrying the box. A brass handle is screwed to the cover. The box is well varnished in order to prevent the spilling of water swelling the wood and spoiling the joints.

Pond inhabitants can be kept alive in bell glasses turned mouth upwards (Fig. 87), or in large wide-mouthed bottles, taking care to maintain the due balance between animal and vegetable life, placing two or three stalks of a suitable pond weed, as *Anacharis alsinastrum* or *Valisneria spiralis*, in the water, and a pond snail or two (*planorbis*) to keep the grass clean. In this way also many forms whose presence was not apparent at the time of filling the glasses will be found subsequently.

It must be remembered that the strictly microscopical types of pond life, those that require to be magnified in order to be seen at all, are very abundant in the colder months of the year. The decaying vegetation at the bottom of a pond, swept in by the winds, containing also the remains of the aquatic plants which wither and die down in the winter,

is a fruitful hunting ground. But it is more convenient to stock the glasses in the late autumn months, and so keep them indoors through the winter. It is better also to have several small wide-mouthed jars like Fig. 87, or globes, than the regular aquarium. By this means partial isolation of species can be made. The specimens are also more easily fished out with the dipping tubes. Moreover, if, through lack of judgment, the balance of life is destroyed and

Fig. 87.—Removing Object from Bell Glass.

the creatures die in one glass, those in the other glasses may be saved. The great thing is to avoid crowding, either of animal or vegetable forms, since they all, as much as human beings, need oxygen in abundance in order to live. The neatest form of receptacle is the common bell glass turned mouth upwards, and resting on a circular block of wood (Fig. 87) turned hollow, and recessed for the glass knob. The knob acts as a steady pin, and prevents the glass from overturning, Glasses ranging from $4\frac{1}{2}$ in. to 6 in. in diameter are the most convenient for

stocking. In addition to these, half a dozen wide-mouthed 8-oz. bottles will be useful. Objects can be lifted from them with "dipping tubes," these being simply lengths of glass tubing of different sizes. To use them, place the forefinger over the upper end and lower the other end into the water until close to the object sought (Fig. 87), then remove the forefinger. The pressure of water will now displace the air previously confined by the forefinger, and the water will rush in to take its place, carrying with it such objects as are in the vicinity of the mouth of the tube.

In all wanderings in search of spoil a pocket lens should be carried, for without its employment very many of the smaller organisms will escape observation. A Coddington lens, or a combination of three lenses, would be the most useful and handy form. A pair of tweezers is also useful at times.

It is desirable always to determine the name of an insect or object before proceeding to mount it, as slides then acquire an educational value. On reaching home after an excursion, the first matter is to identify all the objects and to treat them individually according to their special character. Label all tubes or bottles with the names of their contents, since it is often impossible to identify fragmentary portions weeks afterwards. When objects are all arranged and labelled, the work of dissection and of treating them with suitable solutions can be begun.

For killing objects, chloroform is the best for general use; it is preferable to the cyanide bottle because more convenient and certain. But other methods are used in special cases. Alcohol is often employed when it is desired to keep limbs, cilia, etc., extended as in life; for some marine forms corrosive sublimate in solution has been used with success. Beetles are often killed by pouring boiling water over them.

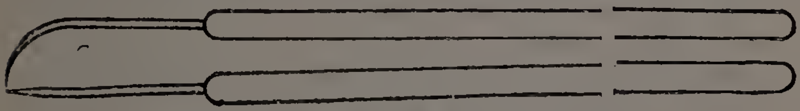
CHAPTER IX.

DISSECTING APPLIANCES.

Skill in the dissection of objects is necessary to the working microscopist; and the difficulties of its acquisition are sufficiently apparent when the extreme minuteness and delicacy of most of the parts operated upon are considered. It is essential, therefore, that he should have suitable appliances.

The instruments used for dissection embrace needles, knives, razors, scissors, lenses, troughs, pins, syringes, brushes, section lifters, section instruments or microtomes, etc.

The needles used in this work are ordinary stout sewing needles mounted in light wooden handles.



Figs. 88 and 89.—Dissecting Needles.

About half a dozen will be wanted—some straight (see Fig. 88), some curved (see Fig. 89), the straight ones being used for the tearing apart, teasing out and separation of structures, and the curved ones for the hooking and drawing away of parts. None of these should stand out more than $1\frac{1}{4}$ in. or $1\frac{1}{2}$ in. from their handles, else they will spring too much in working. To curve needles, it is only necessary to heat them in the flame of a spirit lamp, and turn them with wire pliers. The blunt or eye ends of the needles are inserted in their handles, either by driving them in tightly while held in a vice, or, preferably, to avoid risk of splitting, by boring a hole with a fine bradawl in the handle, and sticking the needle into a matrix of shellac or sealing wax, melted

by heating the needle before thrusting it in. If in any case the handles begin to split, bind them round the ends with a few turns of thread. Since these needles are in continual request for dissections, they should be kept clean, bright, and sharp.

Knives of the shapes shown in Figs. 90 to 92 are used for dissection. They cost from 1s. 6d. to 2s. 6d. each, according to whether they are mounted in ebony or in ivory handles. Five or six are sufficient for most purposes, and the amateur can make most of them himself from the blades of old pocket-knives of good hard temper by careful grinding, and cementing in wooden handles. Thin ward files make good knives when a grindstone is available for smoothing the surfaces and reducing to shape and requisite thinness. These files should be kept very sharp, and free from rust.

Razors are necessary for cutting thin sections of substances, and also for severing the stouter and harder portions or anatomical and vegetable structure. They should preferably be fixed rigidly in handles of wood for these purposes, rather than loosely pivoted in the usual manner. Of scissors there are three kinds used by microscopists: one of the ordinary shape, of moderate strength and stoutness, for general work; another pair, of small size, having curved blades, as being convenient for cutting downwards nearly vertically without risk of injury to parts adjacent; and a special pair of spring scissors, having short, very thin blades, directed forwards and downwards at an angle, the movable blade being pressed by the finger, and opened by a spring immediately the finger is released.

An instrument which, in the absence of a freezing microtome, is of some value in the cutting of sections of soft substances of moderate thickness, is a Valentin's knife, so named after its inventor. It is made in slightly modified forms, but consists essentially of two parallel knife blades, the distance apart of which

is regulated in one form by the combined action of a regulating screw and a pivot working in a slot near the base of each blade, and in the other by the action of a screw alone. The latter form is the better of

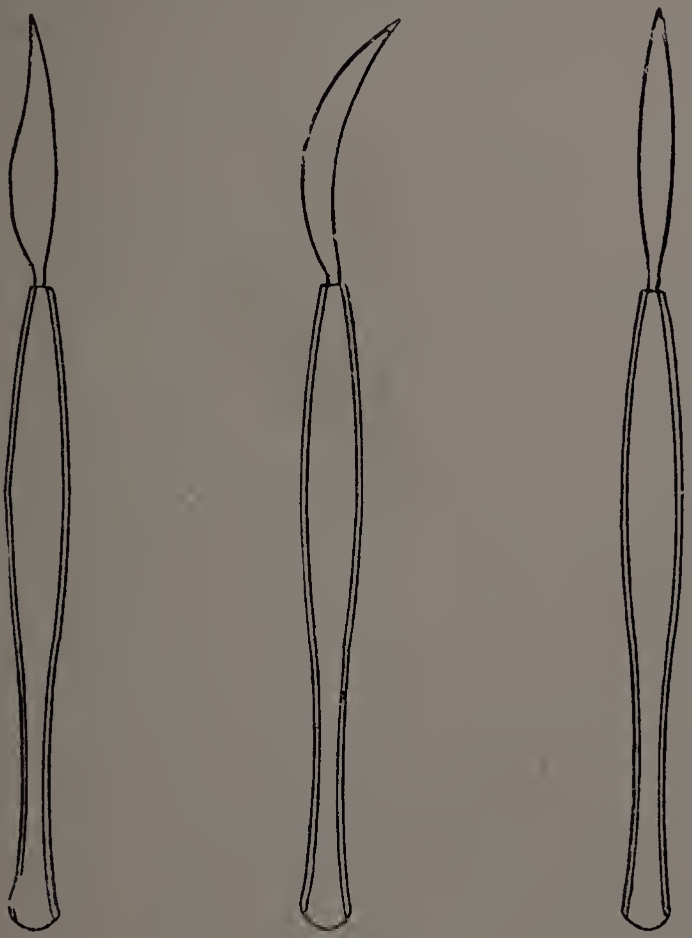


Fig. 90. Fig. 91. Fig. 92.

Figs. 90 to 92.—Dissecting Knives.

the two, and the instrument should have curved blades. But the Valentin knife has been superseded by the freezing microtomes (see p. 96).

With regard to the magnification of objects under dissection, this should not be done with the ordinary

compound achromatic microscope; first, because of the inversion of the image, which renders the manipulation of the needles an extremely tantalising process; second, because of the difficulty of operating upon the stage; and third, because of the injury which many fluids and reagents will do the stage or the optical work. For purposes of dissection, therefore, the simpler the instrument the better; numerous microscopes and magnifiers have been designed specially for this work.

Perhaps the best type of instrument for this purpose is the Ross dissecting microscope. It has a flat circular base which carries a hollow pillar. In this pillar slides stiffly a second pillar, to the top of which an arm is attached by means of a universal socket joint, resembling thus far the common condenser stand. A bar slides through this arm, and carries at one end a metal ring into which the simple lenses employed for dissection are dropped, singly or in combination, according to the degree of magnification required. It is apparent, therefore, that any movement can be imparted to the lenses, precisely as in the case of the condenser, the only difference being that, instead of the rigid attachment of the bull's-eye to its stem, the ring for the lenses is united to its stem with a universal joint to bring it horizontally at any height. The upper pillar can be elevated, depressed, or swivelled; the bar can be slid backwards or forwards in its socket, raised, lowered, and moved through an arc of a circle, and the lens can be maintained horizontally in any of these positions.

A simple instrument can be devised, and one that can be easily constructed. Get a circular disc of metal or the base of an old lamp stand, not too large, and to it attach an upright rod of brass or iron wire about $\frac{5}{16}$ in. or $\frac{3}{8}$ in. in diameter. Procure a stout piece of brass ferrule about 1 in. long that will slide stiffly up and down this rod, and to it attach a bit of $\frac{1}{8}$-in. wire bent round at the end farthest away from

the pillar into a ring to receive the lenses loosely dropping therein. The wire may be tapped or screwed into the ferrule, or it may be brazed or soldered thereon. The lenses can then be focussed to any height within the range of the vertical rod

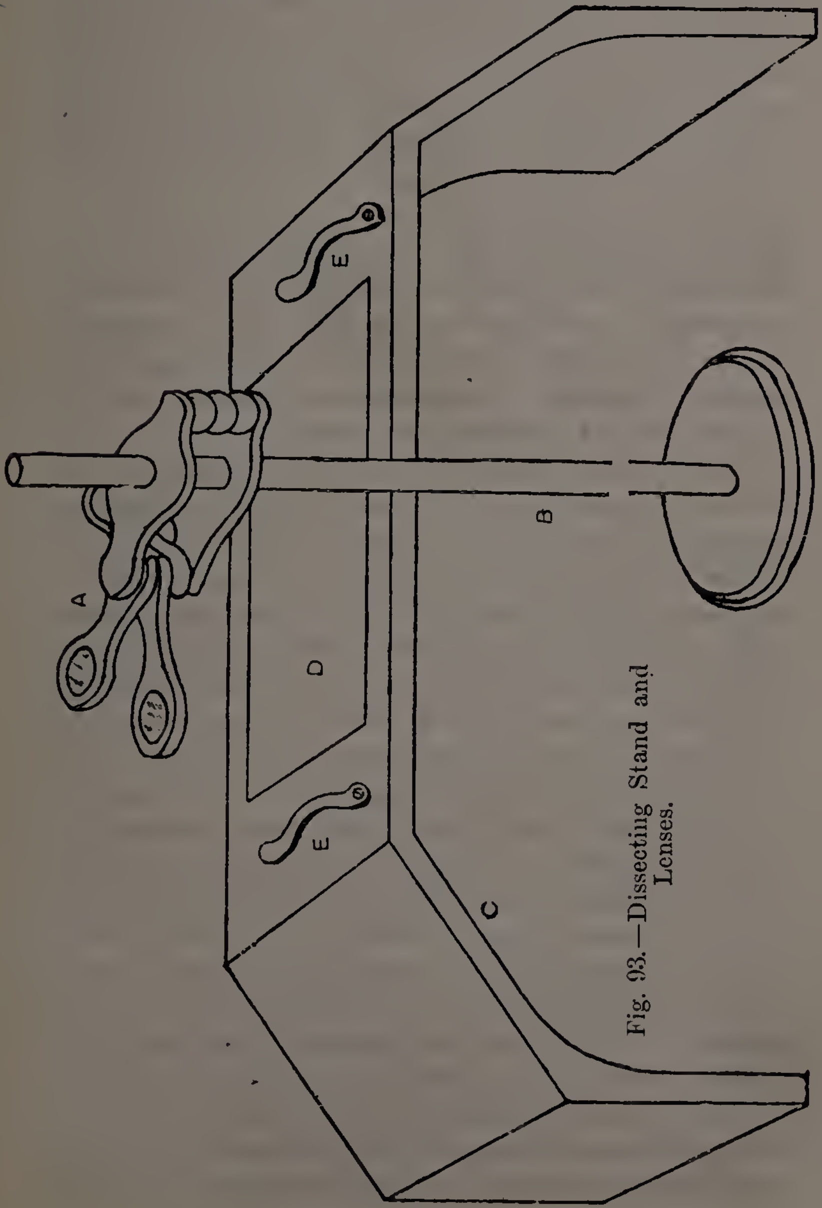


Fig. 93.—Dissecting Stand and Lenses.

and swivelled as well, possessing, therefore, most of the advantages of the universal joint in the more expensive instruments.

Another form of dissecting microscope and stand is shown in Fig. 93. Here the ordinary triple pocket or flower lenses A, mounted in horn, are slid upon a vertical rod B set in a metal stand, giving both vertical and horizontal motions. The stand can be readily made, and the lenses then mounted thereon by drilling a hole through the horn sides. The table C is necessary for transparent dissections, and desirable for all, whether transparent or not. To transmit the light through the object from below, the centre of the table is furnished with a plate of glass D, upon which the dissection is laid out. Commonly, the end supports of the table slope downwards as shown, to afford a convenient resting-place and support for the hands while at work.

There are several forms of dissecting stand designed on this general type by manufacturing opticians. In some the ends are hinged to fold up when not required, while in others they are rigid. The table shown in Fig. 93 is a light rigid brass casting, having a rebate around the central hole to take the glass, which is cemented in with white lead and driers. There are two brass clips E E for holding object slides. In the more complete instruments there is a mirror placed underneath to reflect the light upwards, similar to that under the stage of a microscope.

When dissection has to be carried on under water, as is more often than not the case with insect tissues, a trough is necessary. Troughs are made either in glass or in gutta-percha, and are obtainable in various sizes and shapes, but are commonly rectangular in outline. The gutta-percha troughs are suitable for the dissection of opaque objects, and these are pinned out on the gutta-percha, or, preferably, on a piece of thin cork loaded with lead, lapped round the edges, to sink it in the fluid. In glass troughs the objects

must of necessity be pinned to cork. The pins used are either the small common kinds, or the entomological pins, the latter bending more readily than the former, which is frequently an advantage.

A common glass syringe is a necessary portion of the microscopists' outfit, its purpose being the cleansing of objects under dissection, or the washing of those which have been in solutions. Camel-hair brushes are also used for the purpose of removing from the tissues and portions of anatomy the specks of dust, dirt, and foreign matters which cling to them and mar their appearance.

Section lifters are thin flat blades, bent at a right angle with their handles, and used for lifting delicate dissections out of the fluids in which they have been prepared. Large thin tissues, if lifted out with needles or forceps, would collapse on leaving the water, and become damaged and torn if spread out then on a slide with needles. But they are naturally extended in fluid, and the section lifter can then be introduced underneath without injury to the object. Or, if the vessel containing the specimens to be dissected is sufficiently large, a large cover glass, or an ordinary glass slip, can be employed upon which to lift the specimens out.

A special lamp (Fig. 68, p. 62) also is necessary.

The foregoing has not exhausted the list of appliances used in dissections, but those mentioned are the essentials.

Intimately related to the present subject is that of section cutting, performed to a large extent in that important class of instruments known as microtomes, or section instruments. There are so many different patterns of these made that only the principal types can be noted. Their function is the cutting of extremely thin sections, or slices of substances, either moderately hard or soft, and of uniform tenuity through their entire area. In order to accomplish this, the substance is, in the simplest

microtome, enclosed in a metal tube, and advanced to a minute though measurable distance beyond the mouth of the tube by pressure applied to a piston behind, actuated by a fine-threaded screw working in the bottom of the tube. A knife, razor, or chisel, guided by the end or face of the tube, is made to slice off the precise thickness which projects beyond the face.

The simplest form of microtome, and one which, at the same time, is quite efficient, is that shown in section in Fig. 94. It is grasped with the left hand, the razor or chisel being manipulated by the right. The screw H which actuates the piston J is of fine pitch, and, being tapped into a hole in the bottom end of the cylinder, is rotated by the milled head K. If the substance to be cut is of a hard, say of a woody or horny nature, it is simply dropped into the tube between packing pieces, and pinched by the set-screw L at the side, the grip being sufficient to prevent it from yielding before the knife, while allowing it to obey the almost infinitesimal thrust of the screw and piston behind. A few thick sections are then cut off in order to get a level and clean surface, and then the actual thin sections are cut rapidly in succession, the razor being dipped in water, or in weak spirit, between every two or three slices to make it work the more freely. To remove the sections without fracture from the razor blade, they should be floated off either into water or other fluid, according to the nature and mode of treatment of the sections.

If, however, the substances are soft, such as flower stems, and roots, leaves, or animal tissues, which have been partly hardened in spirit, they must be enclosed in a matrix in the tube before they can be cut. Paraffin forms the best and most generally used basis; a paraffin candle does excellently. This is often used alone, but is apt to crack. A mixture made by melting together 1 part of solid

paraffin, 1 part of paraffin oil, and 1 part of lard, is therefore to be preferred. This is poured around the object in the tube and allowed to harden. When set, the object, with its enclosing matrix, can be cut like a hard substance, and the paraffin dissolved away from it afterwards. In this instance the set screw is not required, since the paraffin forms a solid

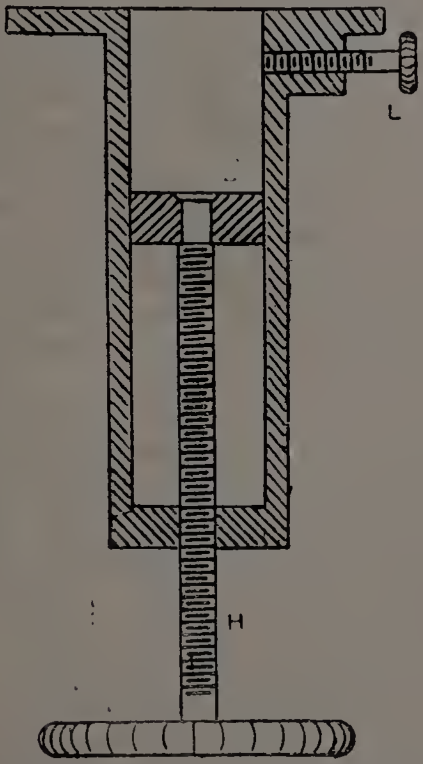


Fig. 94.—Simple Microtome or Section Instrument.

core completely filling up the tube. Other embedding mixtures are used, as (1) white wax and olive oil in equal parts melted ; (2) 4 parts of spermaceti and 1 part of castor oil ; (3) 2 parts of paraffin and 1 part of vaseline ; (4) 3 parts of paraffin, 2 parts of cocoa butter, and 1 part of spermaceti ; (5) 3 parts of paraffin, 1 part of cocoa butter, and 1 part of spermaceti.

By practice, skill in cutting some kinds of sections can be acquired without the aid of a microtome, the object being embedded in a cubical block of paraffin mixed with lard and sliced with a razor. The eye and the sense of touch are then the only guides, and these will not give results so uniform and reliable as the microtome.

Many microtomes are attached to a slab of wood in order that they may be clamped to a table, thus leaving both hands free. Again, the end surface of the tube over which the knife traverses is often made of glass, as being clean and always preserving a perfectly smooth surface. All the more expensive instruments have the milled head divided round so that the precise amount of forward movement of the piston can be readily determined and sections of known thickness cut. Most makers have their own special forms of section instrument, varying in detail rather than in principle.

The type of microtome just described is that in which the substance is cut either in its natural condition, or when previously prepared by some hardening agent as spirit or chromic acid. But there is another type called the "freezing microtome" not so simple or so cheap as these. It was invented by Prof. Rutherford, and is, as its name implies, a section instrument in which the softer substances which would yield before the knife even when embedded in paraffin or wax are rendered rigid by a freezing process. Numerous modifications of the freezing microtome are known; they may be divided into two main classes, those in which ice and salt are used for the purpose of congelation, and those in which a spray of ether is the refrigerating agent.

All substances which have to be cut are embedded in a matrix of gum water—that is, water saturated with gum arabic. This freezes on the table and retains the frozen object with sufficient firmness to allow of the thinnest possible sections being cut.

When the microtome is not held in the hand, or if, being held, a non-conducting piece of baize or flannel is interposed, the freezing action will continue for half an hour or more, amply long enough for dozens of sections to be removed. No one who has once used the freezing microtome would care to be bothered, except when absolutely necessary, with spirit-

Fig. 95.

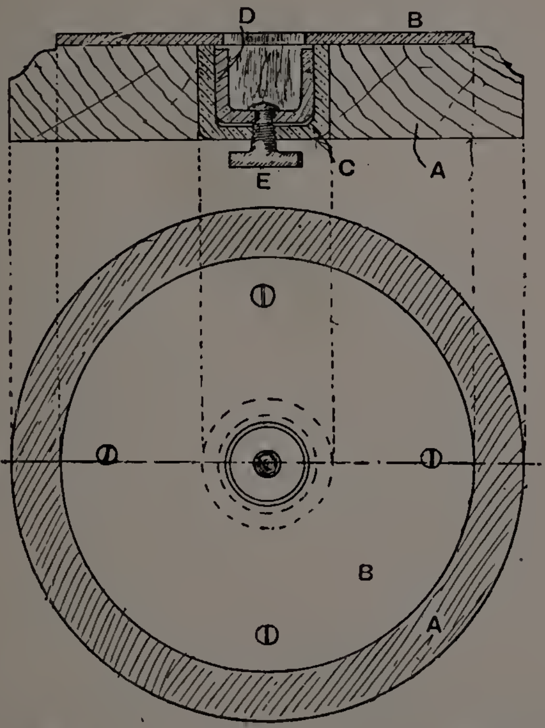


Fig. 96

Figs. 95 and 96.—Section and Plan of Microtome.

hardened substances, which too often cause distortion of the tissues and render them opaque. Ether as a refrigerating agent is preferable to ice and salt, being usually more readily obtainable than the ice.

A simple microtome on a principle already explained is shown in section and plan by Figs. 95 and 96, the method of using it being illustrated by Fig. 97, and it is made in the following manner.

The first thing needed is a disc of wood A, from 4 in. to 5 in. in diameter and $\frac{3}{4}$ in. thick. A wood block, such as is used for fixing gas brackets to walls, suits the purpose admirably, and will be ready turned to shape, moulded on the edge, and polished. In the centre of this block bore a hole, 1 in. bare in diameter, entirely through the thickness. Next cut a circular piece B, of thin brass or zinc, to the same diameter as the top of the wooden block. Before screwing this plate to the block, drill a $\frac{5}{8}$-in. hole in the centre of it, taking care to make it centre correctly with the hole in the block. Then file off the top surface of the plate, and smooth it with emery and oil.

Obtain a blank cap C (Fig. 95)—that is, a piece of brass pipe with one closed end—of 1 in. external diameter, and file it off so as to make the length equal to the thickness of the wooden base. A hole is drilled through the closed end of the blank cap, tapped to suit the thread of a milled-head screw E, which should be about $\frac{3}{16}$ in. in diameter. Cut off the screw, if necessary, to about $\frac{3}{4}$ in. long, measured from under the milled head, and, by filing, or by turning it down in the lathe, form a step $\frac{1}{32}$ in. deep and $\frac{1}{4}$ in. from the end. This end of the screw is to pass through an inner cylinder D, as shown in Fig. 95, and after being inserted must be riveted over to prevent its withdrawal. The inside cylinder, for which another brass blank cap may be used, must be made to fit closely into the outside cap C, but with just enough play to allow it to work easily up and down. The inner cylinder D is cut so as to be $\frac{1}{16}$ in. below the under side of the surface plate B—that is, $\frac{1}{2}$ in. or $\frac{9}{16}$ in. long (see Fig. 95).

When these various pieces have been fitted neatly together, the external cylinder C, with its fittings, is driven tightly into the 1-in. hole previously bored in the wooden base, until it comes up tight underneath the surface plate. The microtome is now

ready for use. When the milled-head screw is turned, the inner cylinder will be raised or lowered within a limit of $\frac{1}{16}$ in., the underneath side of the surface plate preventing it from rising farther.

With regard to the method of using the microtome, suppose it is desired to make a very thin cross section of the stem of a plant. First melt together some white wax and olive oil, or one of the compositions given on p. 95, so as to form a solid block when cool. A small quantity can then be used as required. Take a little of this prepared wax, melt it, and, having turned the milled-head screw so as to lower

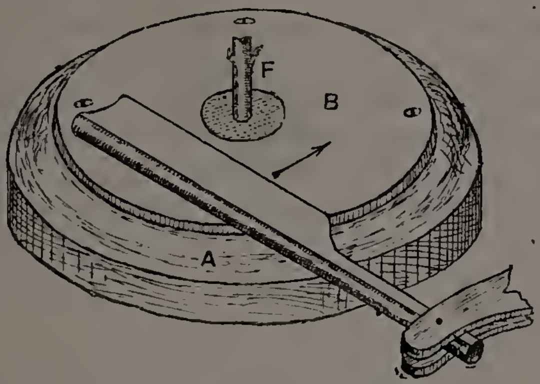


Fig. 97.—Using Microtome.

the inner cup as far as it will go, pour the molten wax through the hole in the surface plate into the cup until the wax reaches the level of the surface plate; then, while the wax is still liquid, stand the plant-stem F (Fig. 97) upright in the middle, as shown. Allow the wax to cool, and then turn the milled-head screw about a quarter of a revolution, so as to raise the inner cup very slightly, and with it the wax and the embedded stem.

Now take an old razor with one of its faces ground perfectly flat, and sharpened from one side only as if it were a chisel. Press the flat side of the razor in close contact with the metal plate, and push it forward, slicing off the top of the wax, and paring

the stem level with the face of the plate. Then turn the milled-head screw very carefully for another quarter revolution, or less, so as to raise the inner cup and wax very slightly higher. Repeat the work with the razor, when it will be possible to pare off an extremely thin slice of wax, with a very thin section of stem embedded in the centre. Do not attempt to handle the delicate section with the fingers, but float it off the razor with a camel-hair brush into a little alcohol, which will dissolve the wax. The section may then be stained, and mounted on an object-glass in the usual way. It may be necessary to add that as the milled-head screw projects below the microtome, a hole should be bored in the bench top sufficiently deep to take the projecting milled-head screw, thus serving the double purpose of allowing the microtome to rest firmly on the bench, and preventing it from sliding along the bench when the razor is being used.

CHAPTER X.

MOUNTING OBJECTS FOR THE MICROSCOPE.

THE only way to gain sound practical knowledge of microscopy is to acquire facility in actual mounting. Bought slides are not to be compared, as regards educational value, with those that are home-made. They are usually better as actual mounts, being made by experts, but it is the knowledge acquired in mounting that becomes valuable. By this is meant not so much skill in mounting, as that intimate acquaintance with structural detail gained in the preparation of objects, which cannot be learned so well from finished preparations. When working with a view to obtain and to preserve one particular specimen, or to reveal one particular aspect of it, a dozen others will come under notice. The same object is presented under many aspects, and different media bring out structural details with different effects; much that is not specially sought for is thus learned—in fact, one needs to be a working microscopist in order to appreciate the inestimable advantages of practical mounting. There are some valuable specimens obtained in foreign countries only, or under exceptionally difficult circumstances, or which are specially difficult to mount, which require to be bought, but these are comparatively few.

Objects that are intended for permanent preservation are mounted on glass slips measuring 3 in. by 1 in. (the standard English size), and protected by covering glasses either with or without an enveloping "cell." The slips, covers, and cells all vary much in quality, and the last two also in size, shape, and thickness. The slips are cut from glass of different qualities, and range in price between about 3s. 6d.

and 18s. per gross, the first-named being of common sheet glass and having the edges unground, the latter being of the finest plate glass and having neatly ground and polished edges. Ordinary slips are cut from flatted crown glass, which is quite good enough for the common purposes of the microscopist, but is not so free from minute specks and pittings as plate glass. For objects requiring low or moderate powers, and for objects of a fair thickness, flatted crown slips are quite suitable. It is when mounts of great tenuity are used, requiring the highest powers of the microscope, that only the finest quality of glass can be used.

The finest slips of all are those termed diatom slips, which are extra thin to prevent undue refraction of the light through them. Flatted crown slips with ground edges should not cost more than 6s. per gross. The thickness of the common slips should average $\frac{1}{16}$ in., but they vary and ought to be picked over, the thinner glasses being reserved for use with high powers, and the thicker ones being employed for ordinary objects. The purpose of grinding is to allow the slides to be handled without injury to the fingers. After being ground, no further finishing is given to the slides; when left unground the edges are covered with ornamental paper. Plain glass slips, however, always look neater than those edged with paper, which harbours dirt and dust. For large objects, extra large slips (3 in. by $1\frac{1}{2}$ in.) are sold, but these are seldom wanted.

The cover glasses are cut from thin unannealed glass, made expressly for the purpose. They vary in thickness from $\frac{1}{20}$ in. to $\frac{1}{500}$ in., the last-named being, as may be imagined, so extremely brittle that some practice is required in order to handle them without fracture. These very thin glasses are, however, only required for the highest powers, where the front of the objective comes very close to them—so close, in fact, that a thicker glass would

prevent it coming sufficiently near to focus. The covers are sold at prices differing with their thickness and shape, the thinnest being the most expensive. Squares cost from 3s. to 4s. per ounce, circles from 4s. to 6s.

For general work, the cover glasses will average about $\frac{1}{100}$ in. in thickness, and can be handled freely and cleaned by breathing on them and rubbing them between the fingers in the folds of a handkerchief. If dirtier than usual, they must be soaked in soda water or in soapy water, and afterwards washed in clean water.

The squares can easily be cut by the working microscopist from sheet glass with an ordinary diamond, but the circles require an instrument, and as this costs about £3 it is not worth while to invest in it. Both squares and circles can be bought so cheaply that it hardly pays to cut them oneself. Five or six shillings an ounce appears to be a high price, but owing to the extreme thinness of the glasses it will include scores of the larger slips and hundreds of the smaller ones. Circles are usually cut from $\frac{3}{8}$ in. to 1 in. in diameter, and the squares from $\frac{1}{2}$ in. to 1 in.; others are also cut oblong. Oval covers cost about 1s. per ounce more than circular covers.

Circles are more largely used now than they were formerly. The making of circular cement cells was a difficult task before the invention of the Shadbolt turntable; but with the aid of this instrument these cells can be struck more readily than those of rectangular form, hence the squares have fallen into comparative disuse excepting in the case of paper-covered slides, for which they are still employed. It will be found better to use circles only as they are less troublesome.

When objects of moderate tenuity only are mounted in balsam and other resinous media, the hardening of the media cements the cover glass to

the slip, and no other fastening is necessary. But when there is a very sensible thickness of balsam, or when the object is mounted in a fluid medium, it is absolutely necessary to use a cell of some sort. This cell is formed either of a cement which is liquid when laid on, but which hardens readily, or of some hard substance which is unaffected by the liquid which it encloses; in the latter case it is attached to the glass slip with a cement that is not soluble in the mounting fluid. A sunk cell can also be used; this consists of a depression ground in the face of the slip sufficiently deep to receive the object to be mounted. In each case the cell is closed with a cover glass.

Cells formed of cement are the most readily prepared, the substances chiefly used being Brunswick black, asphalte, gold size, black japan, and preparations of shellac. None of the first three can be employed with resinous media, as in these they are soluble and will therefore run into the cell in course of time and spoil the mount. For all watery media, however, they cannot be surpassed. For resinous mounts, cements made by dissolving shellac in alcohol or naphtha are suitable.

Objects mounted in Canada balsam or gum dammar, even when they are of considerable thickness, need not be enclosed in a cell, the cover glass being supported at four or more points with beads or slips of glass; the whole will be held together when the balsam hardens. When hard, varnish rings can be put round the covering glass, if required. It may therefore be said that the majority of cement cells are used for fluid mounts, and can mostly be made of Brunswick black, gold size, and black japan. If the cells are rectangular, the cement is painted on with a camel-hair brush guided by hand; circular cells are "ringed," as it is termed, on a turntable (see Chapter VII.). The slip having been centred, the milled collar (Fig. 77, p. 74) is turned

by the forefinger of the left hand, and a camel-hair brush charged with cement is held perpendicularly over that part of the slide where it is desired to make the ring. When forming the rings, beginners very often put on the cement too thick, trying to make a deep cell in one or two ringings. It is much better and safer to put on layers of moderate thickness only than to attempt too much at once. When laid on in quantity, the solvent does not evaporate so well, and the rings spread out to an unsightly width.

A stock of cement rings should be made in spare time, allowing several hours or days to elapse between the forming of each layer. With some practice, the worker will be able to centre and ring on a common turntable (not self-centering) fifty slips in an hour and a half. In this way a stock of cells gradually accumulates, some of which would not be used for months, and would therefore harden thoroughly. This hardening is very important, otherwise in dry mounts the cement is apt to get between the cover glass and the slip towards the centre of the cell, disfiguring the mount. A single layer of varnish will suffice for some of the very thinnest objects, but for others five or six layers will be necessary to bring the cells up to the required depth.

Obviously, the use of cement for cell walls is restricted to the shallowest kinds. For cells of moderate and considerable depth, solid materials are employed; but such a number have been used that it would occupy too much space to enumerate them all here. The following are those most in general use (they are arranged in descending order) :—Glass, tin, ebonite, guttapercha, leather, and cardboard. Of these, glass and tin are used very extensively; the remainder only to a limited extent. Glass is the best of all, as it is unaffected by any of the liquids used by microscopists. Tin, when pure,

is also not acted upon by any of the ordinary fluids, and is cheap. Ebonite and guttapercha are cheap, but become brittle in course of time and are liable to become detached from the slips; they are therefore not recommended for fluid mounts, although, together with leather and cardboard, they are suitable for dry mounts when well protected with layers of varnish on the outside.

The amateur will meet with much disappointment if he attempts to prepare his own glass cells, unless he possesses a lathe and a diamond wheel, when they can be cut as readily as soft metal. But to attempt to cut cells from glass tubing varying from $\frac{1}{32}$ in. to $\frac{1}{8}$ in. in thickness by notching round with a file is almost useless, as the glass nearly always cracks; under these circumstances it is much better for the amateur microscopist to buy the few glass cells which he may require at about 2s. 6d. a dozen.

Tin cells, however, will answer the purpose almost equally well, and cost but 3s. or 4s. a gross, according to size and shape. They can be made by casting tubes in tin about 4 in. long and of the different diameters required. They can be cut off with a fine tenon saw, and finished all over with a file. A better, neater, and quicker method is to chuck them in the lathe, either in a block of hard wood or in some kind of centering chuck, turn them inside and out, and then to part them off with a narrow tool. A few square and oblong cells should be prepared in addition to the circular ones.

Ebonite is so brittle that cells made of it are best bought, but those of guttapercha, leather, and cardboard can be cut out with two gun-wad punches of different sizes, one cutting the outer and a smaller one the inner diameter. All cells are attached to the glass slips with marine glue. This is a solution of indiarubber and shellac in naphtha, and is sold both in the solid and liquid form. The latter is much to be preferred, as it saves the trouble of

melting and spreading over the cell. It dissolves in alcohol.

The way to cement cells to slides is as follows :—A hot plate or mounting table (see Fig. 98) is required. This consists of a piece of cast or sheet brass having four legs screwed or riveted into it near the corners, raising it to a height sufficient to allow a spirit lamp to be placed underneath. Or a plate can be laid on the ring of a retort stand and warmed with a Bunsen burner, or placed on a sand bath. A few slips and cells are then laid upon it

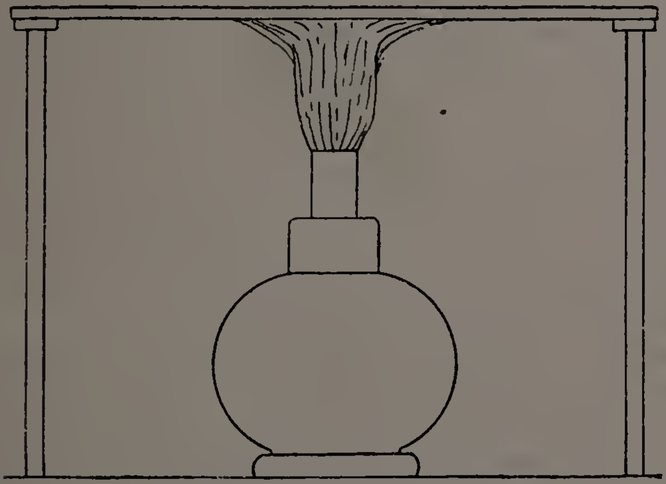


Fig. 98.—Mounting Table.

and allowed to become warm, but not hot. A little marine glue is taken on the end of a glass or wooden rod and spread over the face of a cell, which is then turned over and laid on the centre of the glass slip and gently pressed down with the opposite end of the rod or the handle of a mounting needle, in order to squeeze out the superfluous glue. It is then laid aside in a warm corner, and a small lead weight—such as a bullet—placed upon it. In the course of a few hours the cell will be firmly cemented to the slip.

The methods by which covering glasses are cemented to cells depend on the nature of the media

used. If balsam and dammar are employed, they are their own cements, and nothing further is required to hold the glasses down. But when fluids are used, a cement will be required which will neither affect nor be affected by the fluid it encloses. Gold size and Brunswick black are the cements most commonly employed; Canada balsam is also used either alone or mixed with other substances, such as gold size or litharge and boiled oil.

The method of applying these cements is as follows:—Before the fluid is dropped into the cell a layer of cement, say gold size, is painted round the surface of the ring, and the object and fluid are then introduced carefully, the fluid only in sufficient quantity to fill the cell without running over and wetting the size. This is easier said than done. Many do not paint with size at all, but place the glass directly on the ring; the beginner, however, is likely to obtain better results by following the first method. A little time should be allowed to elapse in order that the size may thicken and become "tacky," and so that the fluid completely permeates the cell to the exclusion of air bubbles; during this time the slide should be covered with a bell, wine, or watch glass, to keep out dust. Afterwards, the cover glass is lowered down gently and pressed upon the layer of size with the wooden handle of a microscopist's needle. If any fluid is squeezed out when doing this, it is either allowed to evaporate or is taken up with some blotting paper and a layer of size painted round with a camel-hair brush in the angle formed between the cover glass and the ring. Fig. 99 shows a section through a slip, cell, and cover, Fig. 100 being a plan. The angles A and B should be filled with a layer of cement to prevent the accidental detachment of the cover or the cell. After an interval of a few hours another coat is painted on, and again another after a similar interval. By these successive applications the cell becomes

hermetically sealed, preventing the escape of fluid or the admission of air bubbles. The cement should be laid on very thinly, more especially in the case of dry mounts. If too thick it will, particularly in the latter, run into the cell by capillary attraction and produce disfigurement; thin coats of cement also harden more equally and are less liable to crack subsequently than when thick and patchy.

For dry mounts of opaque objects, wooden slides are occasionally employed, and are easily made. Slips of wood $\frac{1}{16}$ in. thick, more or less, are planed to 3 in. by 1 in. In the centre of each a hole is bored with a centre-bit to any required diameter —$\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{5}{8}$ in., etc. Slips of card are then cut

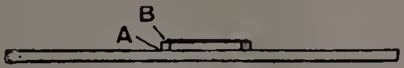


Fig. 99.

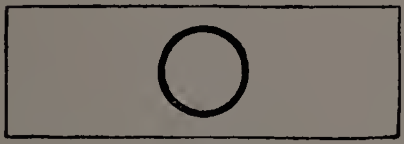


Fig. 100.

Figs. 99 and 100—Section and Plan of Slide.

a trifle larger than the wooden slips, with a piece of dead black paper gummed on the middle. The card is then glued to the wood slip with the black facing inwards, so as to form an opaque background at the bottom of the cell. When dry, the edges are dressed off level. The covering glass is cemented directly to the wood, and the entire slide is covered with ornamental paper.

The covers of slides may be held in place until the cement has set in several ways. Bullets are useful, but the cover is apt to tilt and shift the weight if the mount happens to be thick. Spring clips which grip the slide and cover between them are also used. Figs. 101 to 103 show respectively a

side elevation, a plan, and an end elevation of an appliance that has been found to answer better than anything else for this purpose. It consists of a wooden framework, put together with tenons and dovetails, which carries a number of round rods A pressed down upon the covers of the slides B by the springs C. The springs, which are of hard brass wire of about No. 16 gauge, bear against a short cross wire driven through each rod. The pressure is slight, but it is sufficient to prevent the covers lifting off the slides. Dimensions are not important. The sticks may range from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. in diameter, and from six to twelve in number. The height of the framework is about $3\frac{1}{2}$ in.

Of the many varnishes suitable for use on microscope slides, the following can easily be made at home :—

Sealing-wax varnish is made by dissolving as much sealing wax (any colour) in methylated spirits as the spirit will take up. If a few shreds of gelatine are put in the bottle as well, it will have the effect of absorbing any water with which the spirit may be adulterated, and will cause the varnish to dry with a good bright surface.

For zinc white cement, dissolve $\frac{1}{2}$ oz. of gum damar in 1 oz. of benzine, and add white oxide of zinc until the mixture is quite opaque.

Japanners' gold size may be used either by itself or mixed with various coloured pigments according to taste.

Brunswick black of the ordinary kind makes a very good varnish for finishing slides.

Dull black varnish is made by mixing lampblack with turpentine. This varnish, if properly mixed, should dry with an opaque, dull black surface.

The zinc white and gold size varnishes are the most reliable, as the sealing-wax varnish is apt to shell off when it becomes very dry and old, being too brittle, but it looks very nice when newly put on.

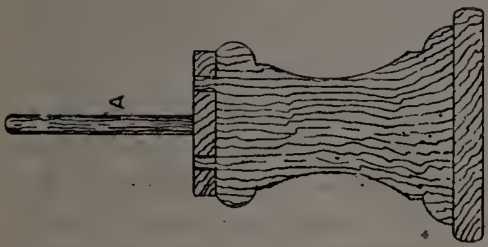


Fig. 103.

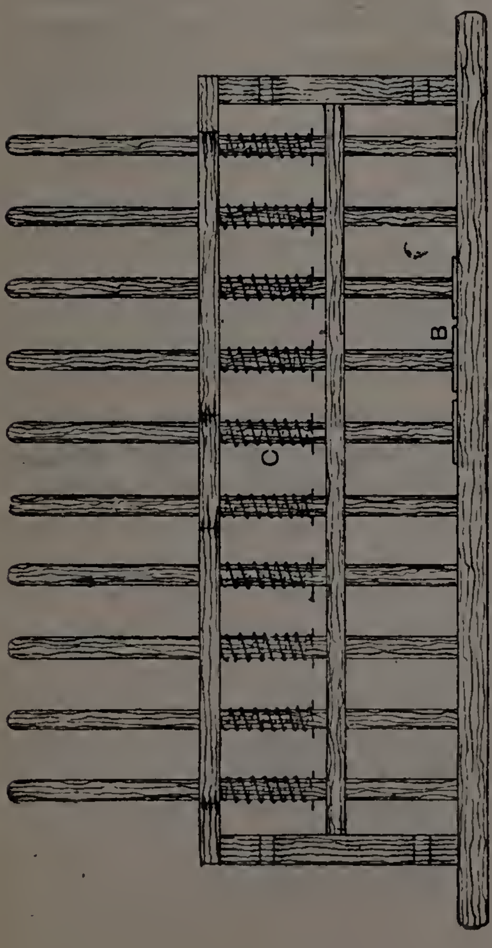


Fig. 101.

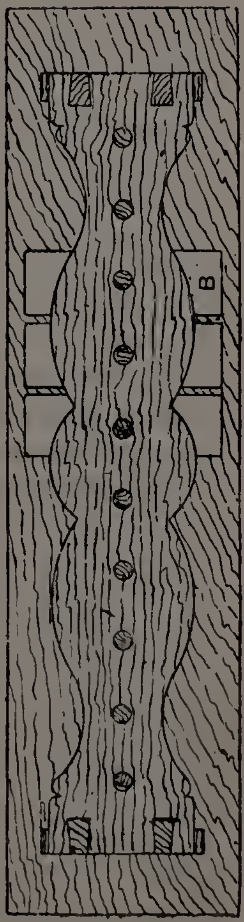


Fig. 102.

Figs. 101 to 103.—Side Elevation, Plan, and End Elevation of Appliance for holding down Slide Covers.

Microscopic objects may be divided into three classes, according to the method of lighting employed in examining them :—1. Opaque objects, which require to be examined by direct or reflected light. 2. Transparent objects, which are best seen by transmitted light; and, 3. Semi-opaque objects, which may be examined either by transmitted light alone, or in conjunction with reflected or direct light.

Opaque objects are the most easily mounted, and require the least preparation, and so a start should be made with them. Suppose, for instance, that the wing of a small butterfly or moth is to be mounted.

Such opaque objects are, as a rule, best examined in their natural state, and without any preparation except the removal of all moisture; and as they are usually of some perceptible thickness, to avoid pressure they nearly always require to be mounted in a raised cell, the making of which has already been explained. Make the inside of the cell black by applying to the surface of the glass and the edges of the cell a thin coating of dull black varnish. When this is dry apply evenly to the top edges of the cell a thin coating of japanners' gold size. The slide should now be put on one side for a few hours, under a glass shade or in a place free from dust, in order to allow the gold size to become "tacky," and when it has reached this stage the cell is ready for the reception of the object, which must be thoroughly dry before it is mounted.

If the object is just large enough to touch the edges of the cell and the under side of the cover, it can be put in without any cement; but if the object is slightly small, the least sensation of gold size, between the object and the bottom of the cell, will have the effect of keeping the former from slipping about and so getting injured after the mount is completed. If gold size has to be applied in this way, it is as well to let it get nearly dry before completing the mount.

When all these instructions have been carried out, select a cover glass sufficiently large to extend about halfway between the inside and outside walls of the cell, and clean it carefully with a fine cambric handkerchief. If a silk handkerchief or chamois leather is used, electricity is set up on the surface of the glass, and particles of dust are attracted.

The cover glass, when cleaned, should be taken in the tweezers, warmed, and carefully placed on the top of the cell, care being taken that the edges adhere all round. The slide should now be placed on the turntable, and a thin coating of gold size applied to the edges of the cover glass, and the whole should be allowed to dry. When dry, another coating may be applied, sufficiently thick to fill up the angle between the edges of the cover glass and the top of the cell walls, and this again may be nicely finished off with coatings of various coloured varnishes, sealing wax, or other suitable substance.

All slides should be carefully labelled as soon as mounted, but it is often inconvenient to do this at once on account of the varnish not being dry. A good plan is to write the name of the object in ink on the back of the slide. This can be cleaned off after the varnish is dry, and a neat label affixed at one end to the face of the slide. The label should state the name of the object, where the object was obtained, date of mounting, method of preparation, and name of mounter.

Various modifications of the above method, to suit different objects, will at once suggest themselves to the careful observer; for instance, the object may be too large for any of the cells in stock. This difficulty may be met by cutting a cell of a suitable size out of a piece of cardboard of the proper thickness, and using a square or oblong cover glass, instead of a circular one.

Again, it may be desired to display both of the sides of the object. In this case proceed as above,

but do not blacken the interior of the cell; take great care to choose a cell of the exact size required, as the object cannot be secured with gold size.

Where there are many objects to mount, the best plan is to prepare a number of slides by cementing cells to them beforehand; but great care should be taken that when the cement is dry the rings adhere at every point, so that there may not be the slightest chance of air penetrating to the interior of the cell.

Be sure that everything inside the cell is dry before the cover glass is put on, and that when the slide is finished it is hermetically sealed. If these two rules are carefully adhered to, there need be no fear of mould appearing on the work.

The mounting of transparent objects for examination by transmitted light will now be explained:

Objects the most divergent, and, at first sight, quite the reverse of transparent, come under this heading, and by careful preparation can be made sufficiently translucent for the most minute details of their structure to be made out. Take, for instance, a piece of coal: who would suppose that anything could be made out of this but the shapeless black mass it appears to be? Yet, by carefully grinding it down to a suitable thickness, it can be made transparent, and its structure can be as clearly defined as the surface of a butterfly's wing.

The different operations involved in the process of preparation of transparent objects are cleaning, hardening, section cutting, staining, and injecting, and it is in these branches that delicacy of manipulation, and care in the choice of mounting media, are most essential.

In mounting opaque objects the object is simply enclosed in its natural state in a dry air-tight cell, but a transparent object requires almost invariably to be mounted in some transparent preservative medium which will permeate its tissues, and, to a certain extent, render the object itself more trans-

parent by increasing its refractive power. The media principally used for this purpose are Canada balsam, gum dammar, and glycerine, with various modifications which will be referred to later.

From a microscopical point of view, the process of cleaning includes the removal of various matters from animal and vegetable tissues, which can hardly be defined as actual dirt; they include natural oils, fatty and muscular tissues, and colouring matters, for instance. Some objects are so soft and flaccid in

Fig. 104.—Canada Balsam Bottle.

their natural state that they have to be hardened before they can be cut into sections or mounted, and, on the other hand, some objects are already too hard and brittle and have to be softened.

Hardening re-agents are alcohol, turpentine, Canada balsam, oil of cloves, bichromate of potash, and picric acid; and for softening, glycerine, carbolic acid, or a weak solution of caustic potash or soda may be used.

Section cutting involves the art of cutting a section or shaving from a large object sufficiently thin to

become practically transparent when soaked in a liquid medium.

Staining consists in colouring the sections, which may at times be too transparent, with suitable dyes and re-agents, so as to bring out in strong detail various points in the structure of the object which before were almost invisible.

Injecting indicates the operation of forcing colouring matter into the minute capillary vessels of an object in order to render them distinctly visible.

Canada balsam is the microscopist's favourite medium, and when the object will stand the rough usage necessary to adapt it for mounting in this medium, it is the best one to use, because once well mounted in Canada balsam an object looks better the older it gets, and there need be no fear of leakage.

Canada balsam as sold by the druggist is hardly suited for the purpose, as it would take too long to harden. For this reason, a portion should be placed for a short time in an open vessel in a moderately warm oven, care being taken to exclude every particle of dust. By this means the volatile spirit in it will be driven off, and eventually the balsam will become almost brittle. In this state a few pieces should be taken and dissolved in chloroform, and the whole kept in a wide-mouthed stoppered bottle for use. A bottle like Fig. 104 is the best form to use, because the balsam does not run down the outside, and the stopper is not liable to stick as in the case of an ordinary bottle. Fig. 105 shows another common form of bottle for this purpose.

The most suitable objects for mounting in Canada balsam are animal sections stained and, or injected, sections of timber and mineral sections, portions of the hard coverings of insects (*Coleoptera* and *Diptera*), diatoms, etc.

Gum dammar may be used for the same class of objects, and should be prepared for use by being dissolved in benzine: It is, in some respects, not

quite so useful as Canada balsam, being more brittle and liable to crack, though, on the other hand, it is almost entirely free from the objectionable yellow colour of Canada balsam.

Glycerine is often preferred as a mounting medium because it is colourless, may be diluted with water to any extent, and will generally assimilate readily with most animal and vegetable secretions, and thus permit the mounting of an object in as natural a state as possible. The great difficulty with glycerine and its compounds is to prevent it leaking from

Fig. 105.—Another Canada Balsam Bottle.

under the cover glass or out of the cell. It has such an affinity for water and such a strong solvent power, that it is difficult to make a really good permanent mount which can be guaranteed not to leak.

Glycerine jelly is sometimes used for mounting vegetable tissues, and may be made as follows :—Take a small quantity of gelatine, and allow it to soak in cold water for two or three hours ; pour off the superfluous water and heat the gelatine gently until it melts. To each fluid ounce of the gelatine add one drachm of alcohol, and mix well ; then add, in the same way, a fluid drachm of the white of an egg, and boil the whole mass until the albumen coagu-

lates. Now strain it through a piece of flannel, and to each fluid ounce of the clarified gelatine add six fluid drachms of pure glycerine, and mix; a few drops of pure carbolic acid should now be added and the whole put into a bottle and allowed to cool. When required for use, the jelly should be melted by immersing the bottle in warm water, and it is as well to warm the slide and cover glass before mounting. Glycerine jelly is not recommended for delicate work, on account of the necessity for the employment of heat in mounting.

Farrant's solution is a useful medium for mounting animal and vegetable sections and dissections; but for the latter glycerine is preferable, either pure or diluted with water and with the addition of a few drops of pure carbolic acid to prevent decay and the appearance of fungi. The following is the receipt for Farrant's solution: Dissolve 4 parts by weight of picked gum arabic in 4 parts of cold distilled water, and add 2 parts of glycerine. The solution must be made without the aid of heat, the mixture being occasionally stirred, but not shaken, whilst it is proceeding. When the gum is dissolved, the liquid should be strained (if not perfectly free from impurities) through fine cambric previously well washed out by a current of clean cold water, and it should be kept in a stoppered bottle containing a small piece of camphor.

Some microscopists prefer to filter the solution of gum through fine blotting-paper in a damp chamber, and to mix it with the glycerine after straining. This is, perhaps, the best plan, and it certainly gives more satisfactory results. The great advantage of this medium over glycerine jelly is that it can be used cold.

Suppose, now, that it is wished to mount a portion of an insect—say the leg of a house-fly or of a beetle—in Canada balsam. Select a glass slip and cover glass, and, placing the object in a drop of water in the centre

of the slide, apply the cover glass gently, and examine with the microscope; there is now seen a densely-black unlovely object, with a number of bristles sticking out of the sides. Take the object and soak it for a few hours in a solution of caustic potash or soda (a bottle to contain which is shown by Fig. 106), or gently warm it in the same. Remove all traces of the alkali by washing the object in clean water, and examine again. The black colour will have vanished, and in its stead will be seen a delicately-coloured, transparent, brown, horny structure, its surface covered with hairs, and beneath the surface

Fig. 106.—Caustic Potash Bottle.

traces of muscular tissue distinguished by minute cross lines.

If there are any particles of dust adhering to the surface remove them by gently brushing the object in water with a camel's-hair brush, and then, in order to expel the water, which will not mix with the balsam, immerse the object in alcohol. The alcohol also will not mix with the balsam, but it will mix with oil of cloves, which, in its turn, will mix with the balsam. Remove the object from the spirit to the oil of cloves, and leave it to soak for a few minutes while a slide is prepared.

After thoroughly cleaning a slide, warm it gently over a spirit lamp, and with a pointed glass rod place in the centre a drop of the prepared Canada balsam not containing any air-bubbles. With a dissecting needle remove the object from the oil of cloves, and place it gently in the drop of balsam. Take a clean cover glass, and warming it also, place it gently on the top of the whole, as in Fig. 107. Resting one edge of the cover against the points of the tweezers, support the other with the dissecting needle in the manner illustrated. As the cover glass is lowered by withdrawing the dissecting needle, the balsam should fill up the space between the centre and the edge of the cover glass, but if it does not do so, apply another drop to the edge, and it will at once run in.

If examined now, the object will be seen to be brilliantly clear, and all the points of its structure distinctly visible. The slide should now be put aside in a warm, dry place for a day or two, in order to allow the balsam to harden, and if there is any superfluous balsam at the edges of the cover it should then be carefully removed with the help of a rag and a little benzine, left again for a day or two, and then ringed with varnish, when it may be finished off and labelled in the usual manner.

It is necessary to exercise great care in lowering the cover glass on to the balsam in order to avoid the introduction of air-bubbles, but if, in spite of such care, a bubble is found to have been accidentally entrapped, it can generally be induced to find its way to the edge of the cover glass by pressing the top with a clean dissecting needle. When the bubble has been got outside, prick it with a hot needle, which instantly destroys it.

As the method of preparing objects for mounting in gum dammar, as well as the actual process of mounting, does not differ from that employed for mounting in Canada balsam, it is hardly necessary to recapitulate, and it will be sufficient to give just

a few hints as to the best way of preparing the medium itself for use. It should be prepared as follows :—

Choose a few clean and clear pieces of the gum and drop them into a little pure benzine. When the gum is dissolved, if the solution is not perfectly clear, strain through several thicknesses of fine dry muslin which has previously been washed quite clean by passing through it a strong stream of cold water.

The solution should now be perfectly clear, and like the solution of balsam, of about the consistency of olive oil, or perhaps slightly thinner. It should

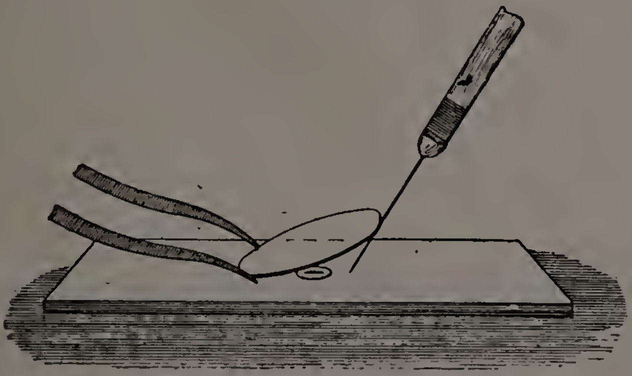


Fig. 107.—Mode of Mounting Object on Slide.

be kept in a similar bottle, which, indeed, will be found a very convenient form for keeping all kinds of mounting media in, as it is important that all dust be most carefully excluded. This is almost impossible in the case of an ordinary corked or stoppered bottle, for when the medium is in use the cork or stopper is bound to be placed on the table on its side, or with the bottom turned up, in either of which positions it is sure to pick up fragments of fibre and dust from the atmosphere or the table, and these subsequently find their way into the medium.

Glycerine is one of the most useful mounting media, and is capable of yielding some beautiful

results. It is not suitable for mounting diatoms and some crystals, but these are exceptions, and, as a general rule, every class of object is better displayed and is seen to greater advantage in glycerine than when mounted in any other medium; and there are many objects which from their very nature it would be impossible to mount successfully in anything else. It is in glycerine, too, that those beautiful preparations of insects are preserved, so as to retain as nearly as possible their natural form and colour.

Glycerine as a mounting medium is capable of endless modification. The preparation of glycerine jelly and Farrant's solution have already been referred to. The other two forms in which it will be found most useful are (1) in its natural state with the addition of a little pure carbolic acid, and (2) diluted with water and a trace of carbolic acid.

Glycerine jelly is useful for mounting sections of green wood either stained or unstained, roots, leaves, some of the coarser forms of algæ, and, generally speaking, objects which without deterioration will bear the slight amount of heat requisite for mounting in the medium, but will not stand the drastic course of treatment necessary for preparation and mounting in Canada balsam.

The objects referred to above require very little preparation except just carefully washing in water, and then soaking in pure glycerine for a few hours previous to mounting; and when the object is thoroughly saturated with glycerine (which should be the strongest and purest obtainable) it should be transferred direct from the glycerine to the centre of a glass slip, all superfluous glycerine carefully removed with the help of a piece of blotting paper or rag placed at the side, and then, after gently warming the slip, a drop of warm glycerine jelly should be placed on the top of the object with a

pointed glass rod, and the cover glass applied in the usual way.

Some workers prefer to get the object into position on the cover glass first and then invert it on the slip. If this plan is pursued, after carefully cleaning both cover glass and slip, breathe on the end of the slip and then place the cover glass on the condensed moisture; it will adhere quite firmly enough to remain in position whilst the object is being arranged, and when this is done, the cover glass should be gently pushed with the tweezers to detach it from the slip and deftly inverted in the centre of the slide.

The glycerine jelly should now run out to the edge of the cover glass, but if it does not, another drop should be added at the edge, which will at once run in and fill up the vacant space. The slide should now be put aside to cool, and then it should be ringed with gold size, and finished off and labelled in the usual way. With a little practice, it is possible to make exceedingly neat mounts in this way, the great object being to get exactly the right amount of the medium on the cover glass, so as to avoid the necessity of cleaning away superfluous medium before ringing.

Farrant's solution is a useful medium for mounting the more delicate kinds of algæ and delicate vegetable and animal sections. Assuming that some suitable sections are already cut and stained, and are now lying in spirit or in a solution of carbolic acid in water, the chances are that the sections will be all curled up and mixed together in an almost indescribable mass. If this is the case, they should be emptied out into a basin of clean cold water, when they will gradually separate one from the other, and the most suitable ones for mounting can then be picked out with a dissecting needle. As they are picked out, they should be dropped into clean spirit, and when they are thoroughly soaked in this, a watch glass

or small porcelain tray should be filled with clean cold water. Having selected the section it is desired to mount, it should be lifted out of the spirit on the point of a needle and placed upon the surface of this water. The result is almost marvellous; no matter how much the section may be curled up in the spirit, as soon as it touches the surface of the water, it will lose all its folds instantaneously, and becoming *perfectly* flat, float upon the surface of the water.

To make a tool for transferring it to the slide without crumpling it up again, take a short piece of stout brass or copper wire and a piece of thin sheet brass or copper shaped as in Figs. 108 and 109, and solder the two together as shown. Place the spatula gently underneath the section, lift it out of the water and slip it off on to the slip or cover glass prepared for it. A small camel's-hair brush will assist in making the transfer, and when the section is in position remove the superfluous water with blotting paper as before. Now place a drop or two of Farrant's solution on the section and apply the cover glass. It will take some few days to dry properly, and sometimes a mount which appeared to have no lack of medium when put aside will, a few days after, have some large vacant spaces at the edges. This can only be remedied by adding more Farrant in the usual way, and then when the edges are finally dry, the slide can be ringed with gold size and finished off as before.

It is necessary before ringing any glycerine mounts, to make quite sure that the surface of the cover glass and of the slip around its edges are perfectly dry, otherwise the gold size will not adhere, and the result will be that after a certain time air-bubbles will appear.

Of the many cements employed for the purpose of resisting the solvent power of glycerine, ordinary gold size is, after all, the best, with, perhaps, the exception of an indiarubber cement made by dis-

solving pure rubber in wood naphtha. It is most important that the cement, whatever it is, should be very firm and adhesive, and not liable to crack when dry.

Mounting transparent and semi-opaque objects in cells now remains for consideration. Cells, as already stated, are used for the purpose of preventing the object from being subjected to pressure, and so crushed out of shape; but, as in the case of dry mounts, so with transparent objects—it is especially essential that the cell chosen should be of the right thickness. This is even more important in the latter than in the former case, because if the mounting medium used is a fluid, the object is exceedingly

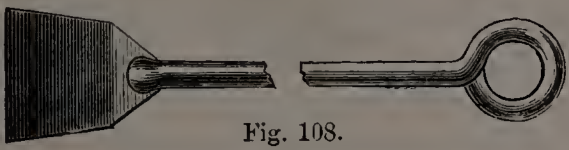


Fig. 108.

Fig. 109.

Figs. 108 and 109.—Front and Side View of Spoon for Transferring Sections to Slide.

apt to slide about in the cell if the cell is in the slightest degree too deep.

The choice of materials for the cell walls is also more limited, as it is always necessary to make the cell wall of a material which is not porous; the medium would leak through a porous material.

"Built-up" cells, that is to say, cells built up of slips of glass cemented together on the slide, are sometimes advised, but for practical purposes these are never required. The ordinary vulcanite or glass rings are amply sufficient for any ordinary purpose, and if it becomes necessary at any time to use an exceptionally large cell for any particular purpose, one may be cut from a piece of good sheet indiarubber and cemented to the slide.

For cementing the cell to the slide, marine glue is, perhaps, one of the best cements to use, and in order to make the cell walls quite impervious, they should be coated with a thin layer of gold size after the cell is fixed on to the slide. The coating should extend just over the outer and inner edges of the glue. Marine glue is, however, at times, somewhat difficult to work with, and the cements sold for sticking glass together (compounded mostly of isinglass and acetic acid) may be used with facility.

The media used for mounting in cells are the same as before, namely, Canada balsam, gum dammar, glycerine jelly, Farrant's solution glycerine, and dilute glycerine; but it is particularly necessary in using Canada balsam to dry the balsam very thoroughly before dissolving it in chloroform. Again, in using balsam, the cells must not be fastened on with marine glue, because the chloroform will act on the gold size and glue and spoil the mount. Cells fastened on with isinglass cement should be used with this medium, and after placing the object in position, it should be covered with a watch-glass and put aside, to allow the chloroform to evaporate, then more balsam should be added until the cell is quite full of hard balsam, when the cover glass may be applied in the manner described hereafter. Balsam labours under a great disadvantage, in so far that it is difficult to get it sufficiently hard and dry before applying the cover glass, and the result is that, the cell having been nicely varnished and put aside as finished, some time after it may be found that the cover glass has cracked across or collapsed in the middle, caused by the further drying and consequent contraction of the Canada balsam.

Many of the fresh-water algæ, such as *Batrachospermum*, whose beauty is much impaired by pressure, look exceedingly well when mounted in a cell in glycerine jelly. They should be prepared by soaking in strong glycerine for a day or two previous to

mounting, and as, in some cases, objects of this class are too fragile to stand even the slight amount of heat required to melt the jelly, they require to be mounted in glycerine alone, with a trace of carbolic acid, or even dilute glycerine consisting of about equal parts of distilled water, pure glycerine, and a few drops of pure carbolic acid. It is here that the great difficulty comes in.

Glycerine easily mixes with water, and therefore readily unites with most animal and vegetable secretions, but, for this very reason, has the disadvantage of interfering very materially with the effectual sealing up of a cell, because neither glycerine nor water will unite with anything of the nature of

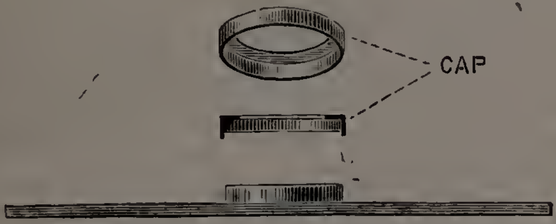


Fig. 110.—Cap for Securing Cell.

turpentine; consequently, if there is the slightest trace of glycerine or water in the top of the cell wall when ringing the slide with gold size, the gold size will not adhere at that point, and the result, sooner or later, will be a leak, which is undesirable. On the other hand, it is impossible to use a spirit varnish, because the spirit would run in at once.

The following ingenious method of getting over the difficulty has been devised. A small metal cap (see Fig. 110) is made to fit exactly over the top of the cell, and when the cover glass is in position, and as much of the medium as possible wiped away, particularly from the top and edges of the cover glass, a layer of gold size is applied to the edges of the same and the top of the cell wall, and then the little cap is placed over all. This holds the cover firmly in posi-

tion, and the slide is placed on the turntable, and a good layer of cement applied to the outside of the whole. If this is carefully done, and good gold size and indiarubber cements applied alternately, an exceedingly strong and neat cell is the result, and there need be no fear of breakage. As already stated, the great thing is to see that all trace of glycerine or water is removed before applying the varnish.

Objects suitable for mounting in cells cannot require much preparation. They must be altogether or almost transparent, to begin with, or, at any rate, quite capable of being easily rendered transparent by the ordinary methods of maceration in water, caustic potash, or soda.

Vegetable preparations do not require and cannot stand much of this treatment. Soaking in glycerine before mounting is usually sufficient, but preparations of insects, or portions of them, require careful and discriminating treatment.

Some of the very dark Coleoptera with hard carapaces require soaking, or even boiling, in strong potash or soda, before being fit for mounting; others, again, with softer coverings, require only soaking. For some insects, again, the re-agents mentioned are too strong, and pure carbolic acid must be used, and for others even this is too strong, and the carbolic acid has to be diluted with glycerine. This last method is the one used for preparing specimens of insects in their natural form and colour without pressure, and by it some very beautiful results may be obtained—the object being, after preparation, mounted in dilute glycerine.

It is often extremely difficult to get the object (say, the head of a bee or wasp) firmly fixed in the cell so that it will not move about, and this, notwithstanding the great care taken in selecting a cell of the right thickness. This defect may be remedied by taking a piece of glass tube and drawing it out to

a thread. Now take a piece of this thread just the breadth of the inside of the cell, and thrust it right through the object from side to side. If the ends of the glass thread are now placed against the inside of the cell walls, the object will be securely fixed in position, and a source of annoyance removed. The glass thread, when immersed in the medium, is not in the slightest degree unsightly, nor is it in the way.

It is far more necessary to be careful to exclude air-bubbles in mounting in cells than when mounting in the ordinary way, because they cannot be squeezed out. Hence, after filling the cell with the mount medium, its interior should always be carefully examined, and if any air-bubbles are found adhering to the bottom or sides, they should be removed with the point of a needle. There should be just enough medium in the cell to form a slightly convex surface when the object is immersed, and the object should be allowed to remain in the medium for a few minutes before applying the cover glass, in order to allow any air-bubbles that may be attached to it to rise to the surface. These should then be removed, and then the mount may be completed as follows :—

Take a clean cover glass—warmed, if the medium is Canada balsam—and, allowing the right-hand edge to rest gently on the top of the cell wall at the left-hand side, push it gently forward until it touches the medium. If there is the right quantity of medium in the cell, the cover glass will now of itself go into position by the force of capillary attraction, and all that is necessary further is to squeeze out superfluous medium by gently pressing the top ; clean it away, apply the varnish, then the cap, and after further varnishing and drying, the mount is complete.

It is only necessary to add that in all microscopic work cleanliness and neatness are of the very greatest importance.

When objects are not required to be properly

mounted they can often be examined with advantage by placing them on a clean slip in a drop of distilled water. Impure water, liquids in general, insects, and other specimens suspended in water, such as diatoms, desmids, etc., can be held in a live cell or live box slide. This may consist of an ordinary glass slide A (Fig. 111), 3 in. by 1 in., such as is used for mounting objects. In the centre of this is placed a thick indiarubber ring B with a cover of thin glass C 1 in. square. The ring and cover are held together on the slide by two springs or brass clips D with screws, as shown in Fig. 111. These clips are made out of a piece of thin brass bent over the slide, and having a perpendicular arm bent at

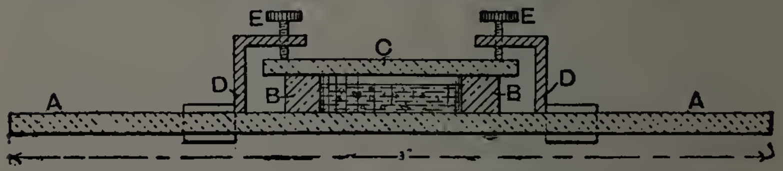


Fig. 111.—Live Cell.

right angles at the top, where it is drilled and tapped to take a thumbscrew E. By screwing down the heads, the glass cover is made to press on the rubber ring and keep the whole cell water-tight. A ring such as is used in lemonade bottles will be found very suitable. By using rings of different thickness, the cell can be made of different depths to suit the various requirements of large or smaller insects.

This cell has the advantage also of being readily taken apart for cleaning. The two screw clips could even be dispensed with, and in place, two small rubber bands used to hold the cell together, thus forming an efficient live cell, readily made out of the commonest materials, which can be obtained by anyone at practically no cost. The ordinary form of live cell is illustrated by Fig. 112.

A useful appliance in mounting, etc., is a mechanical finger. Occasionally one wishes to pick up a diatom

or other small object in mounting, and the mechanical finger is about the only thing with which it can be done successfully. A slip of wood is held in place on the side of the microscope tube by rubber bands. The end of this slip is split, and in the split is placed a cat's whisker. This is so pointed and stiff that it makes a good implement for the purpose. Arrange the whisker so that the point of it is in focus, and then spread the material on a slip. Pick out a diatom, and after moistening the point of the whisker slightly, rack it down, and the diatom will adhere to it. Raise it up, and place the slip on which it is to be mounted on the stage. The surface of the slip must, of course, be prepared with a gum solution,

Fig. 112.—Ordinary Form of Live Cell.

and as the diatom touches it, it will leave the whisker and adhere to the slip. This is not offered as a substitute for the regulation mechanical finger entirely, but it is a simple appliance that is easily made, and will often be found useful by those who do not possess something better for the purpose.

Few persons have any knowledge of the exquisite form and colour to be seen by the aid of the microscope and polariscope in a properly cut and mounted rock section. Some rock sections will appear almost uniformly transparent and without difference of structure by ordinary light, but when seen by polarised light will appear literally ablaze with colour.

No very special knowledge is required for this work; patience and delicacy of touch, however, are essential. The following materials will be required for mounting rock sections :—2 oz. of Canada balsam

in a wide-mouthed jar; 2 oz. benzol (not benzoline); a shallow glass dish; pieces of plate-glass $1\frac{1}{2}$ in. square (any number—say 1 dozen); a small Bunsen burner or lamp. A small oven will also be required; it can be made of sheet-iron, and should be 6 in. high, 6 in. wide, and $3\frac{1}{2}$ in. deep from front to back. At distances of 2 in. and also at 4 in. from the bottom, make two holes on each side and opposite each other. Stout wire must be put through these, so that the slides, when ready, can lie on them to be baked. The oven must stand so that the lamp can be placed under it; by carefully adjusting the lamp or burner, any degree of heat may be obtained. The front of the oven must be closed with a lid or door. In addition to the foregoing, ordinary 3 in. by 1 in. glass slides, and an ounce or two of glass covers, will be necessary.

When buying the balsam, take care that it is perfectly free from specks or dust. When procured, it will be far too thick for use; place a little in a glass jar with about the same quantity of benzol. It must be of a consistency to run off slowly from the end of a stick, and must be kept securely corked, to keep it free from dust, and also because it is exceedingly volatile and inflammable.

Having succeeded in cutting a slice off a rock, place it on a lap, which is supplied with emery and water, until it is ground to a level surface. It will still be rough from the emery. Now take a smooth disc of iron about 6 in. in diameter, with the face turned very slightly convex. This convexity is an advantage, as there is always a tendency to rub a section thin on the edges if the iron is perfectly flat. The specimen is rubbed on this disc with putty-powder, which will bring up the surface to a polish. Hold a square of plate-glass over a lamp and make it hot; then place a little hard balsam on it, and when softened, place the rock on it with the flat surface next the glass. Great care must be taken

that no air bubbles are between the two surfaces; which must practically be in contact. The specimen must be now laid on one side for a day to get perfectly hard. It will save time to prepare a number together. When the cement is hard, the rough side of the rock must be ground away. But now comes the need of great care and delicacy in handling. The section must be watched as it grows thin, as one moment too long on the lap means ruin. It will soon begin to transmit light. With a glass, see if the surface is ground fairly even. When it is reduced to the thinness of a micro glass-cover, proceedings must be stayed, and the work completed with putty-powder on the iron plate, as before described. Examine again with a glass to see if all scratches are removed.

Reducing on the plate will, of course, be very slow, which is what is needed, for a rub or two too many may destroy all the previous labour. With very little experience in the work, however, the operator will instinctively feel when the critical point is reached. Presuming the section transmits light, two points will determine when the work is completed—namely, the section must be of equal thickness all over, and it must be free from scratches.

Having brought the work to this point successfully, it must now be removed from the glass plate. To do this the sections must be placed in a wide-mouthed jar. Benzol must be added until the glasses are well covered. A good plan to exclude all dust is to invert a larger glass jar over it. In an hour or two the cement will be dissolved. In the meantime the slides will have been prepared. Supposing there is not a turn-table for centering, etc., it will be necessary to devise some means by which the sections can be fixed centrally on the slide. On a card draw a parallelogram 3 in. by 1 in., and in the centre place a dot. Place the slide on this, and fix a dot of ink over the one on the card. When

the ink is dry, carefully clean the other side on which the section is to be laid. The glass covers, too, must be made perfectly clean and free from dust.

Various methods are given for cleaning the covers. Use an old silk handkerchief or a linen one (not cotton, that is always fluffy). Place the handkerchief over the right hand, covering the fingers and thumb, then grasp the cover between the finger and thumb. It is now between the handkerchief under equal pressure, when the danger of fracture is almost *nil*. It can be removed by the left finger and thumb, holding it at its diameter.

Now proceed to mount. Take a little of the mounting medium already described, on the end of a clean penholder, and drop it right over the dot on the slide. With a pair of forceps lift out a section resting on its glass slab. No attempt must be made to lift it off, but with a needle fixed in a wooden handle it must be slid off on to the slide and placed with its centre as near as the eye can judge over the dot. Place a drop or two of the medium on the section. Now take a cover between the finger and thumb at its edges; bring it to the slide in a slanting manner so that one edge touches the slide, and let it fall. If it is laid on flat, air bubbles will most certainly be included. It may now be laid on one side for an hour or two, with a small weight placed on it, which will force out some of the medium, and bring the surfaces in contact.

When as many as will fill the oven have been prepared, it should be heated sufficiently hot to bake the slides, but not hot enough to burn or boil the cement, or discolouration and bubbles will be the result.

It should be said that a special oven is not a necessity; the kitchen oven may be used, and has been many a time with good results. This, however, must be left to the inclination of the operator.

The heat will drive off the benzol and turps, and leave the cement hard. When this is done the slides should be taken out and allowed to cool. The superfluous cement must now be removed with a knife, and finally cleaned with a rag dipped in methylated spirits; do not use benzol, which might run under the cover and loosen it.

Tickets or labels should be fixed on the slides, preferably giving the name of the rock, and the locality if this happens to be known.

CHAPTER XI.

A POLARISCOPE FOR THE MICROSCOPE.

The possessor of a microscope who has not a polariscope amongst the accessories to his instrument has hitherto denied himself one of the most fascinating and instructive pastimes which the microscope affords. Under this instrument some of the most uninteresting slides, which have, perhaps, long been put on one side as being not worth looking at, will assume a beauty of colour and definition hardly credible.

The price of the polariscopes sold by the optician has no doubt prevented many from purchasing one. This chapter will show how to make a polariscope for a few shillings in place of twenty-five shillings or more generally asked by the optician.

As this is not an optical treatise on polarised light, the student who wishes for a full definition must be referred to one of the many handbooks on optics. Suffice it to say that a beam of light is polarised, or split into two, as it were, by being passed through a prism of Iceland spar specially cut, or through a bundle of glass plates inclined at an angle of 35°, called the polariser. Half the beam of light thus divided is transmitted through the object, and, after being again passed through a second prism or number of glass plates called the analyser, assumes its original form. The result is that the object is suffused with various colours, according to its thickness and structure. This has the effect of bringing out those parts of the object which, under ordinary transmitted light, appear almost quite transparent and void of detail. As the polariser is turned round on its axis the object will be seen to change its colour, each part taking the

complementary shade to that which it was before. Thus one slide can be made to assume a number of different aspects, according to the conditions and adjustment of the polariscope.

The polariser is placed between the mirror and the stage, and is generally made to fit into, and turn round in, the substage. The analyser is placed in the body-tube of the microscope just above the objective. To do away with the chief cost bundles of glass plates can be used in place of the prisms; and although the result will not be quite so good,

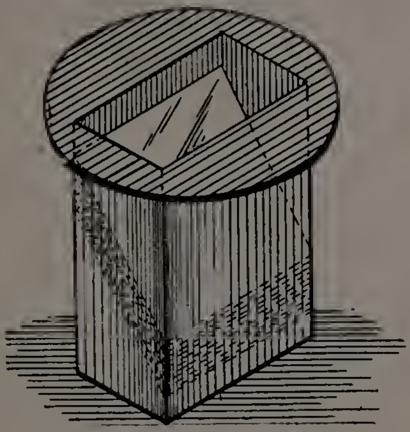


Fig. 113.—Polariscope.

it will repay the little trouble to make it. First obtain at an optician's some of the thin micro-glass, such as is used for covering the objects in mounting slides. The largest sized squares that they cut will be necessary, namely, 1 in. This very thin glass is sold by weight, ready cut into squares and circles; $\frac{1}{4}$ oz. will be enough, and will cost from 1s. to 1s. 6d., according to the quality of the glass.

The polariser complete is shown in Fig. 113. It consists of an oblong tube made from thin card, with from twelve to eighteen glass slips, shown by the dotted lines, placed at the proper angle of 35°.

Take a piece of thin card and mark it half as large again as Fig. 114. Score lightly down the lines at E, F, G, and H at the back of the card, fold it over neatly, and join at the flap left for the purpose (C).

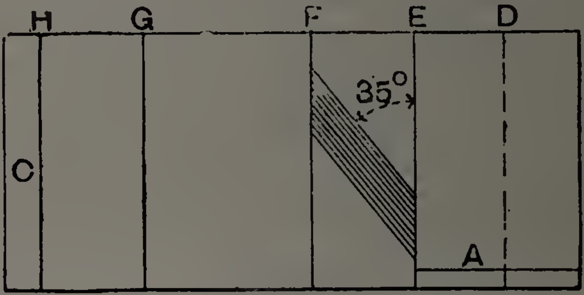


Fig. 114.—Plan of Polariscope Tube in the Flat.

Take a thin strip of cork or wood, and glue it at the bottom of the tube, inside. This forms the ledge for the plates to rest on (A). Cut out a circle of stout card (Fig. 115) a little larger in diameter than the sub-stage, and fit it on to the above tube, with pieces of cork underneath to give support.

Paint the tube black, both inside and out; when dry, carefully wipe and clean the glass slips, and drop them one by one into the tube, seeing that they rest carefully on the ledge A. When these are

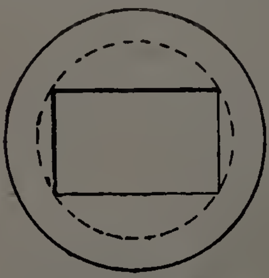


Fig. 115.—Polariser.

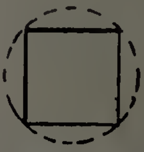


Fig. 116.—Square for Polariscope Analyser.

in, glue another slip at the top to hold them in their place, and the polariser is then complete.

The analyser is made in exactly the same manner, except as regards size. The tube must be of such

a size that it will fit readily inside the body-tube of the microscope, just over the object glass. It will therefore be necessary to mark out the plan with the broadest sides only half as large as before, the correct size being shown by the dotted line D. This will make the tube almost square, as at Fig. 116, which is two-thirds size. This tube can easily be fitted into the microscope with pieces of curved cork.

The glass plates for this analyser will require to be 1 in. by ½ in., and must therefore be cut in half with a diamond. Care must be taken in the cutting, as the glass being so thin, the diamond will probably

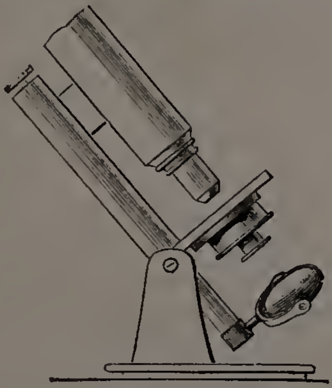


Fig. 117.—Microscope with Polariscope Fitted.

cut right through. Place the glass on a smooth flat surface whilst cutting. Should the sub-stage of the microscope not be large enough to fit the polariser, it can easily be made a size smaller by cutting the plates in half.

For those who desire better results than are obtainable with glass plates, a pair of prisms unmounted can sometimes be obtained second-hand for a few shillings; these can be mounted with cork in brass tubes (see p. 142).

Some slides of selenite will be required; when placed just above the polariser, they will further change the colours and give very pleasing results.

The construction of a sub-stage and polariscope of a slightly different kind will now be described. Fig. 117 is a diagram showing the microscope with polariscope fitted, and Fig. 118 shows the underside of stage, with the two positions of sub-stage. The fitting consists of four portions: the sub-stage, fitting for polariscope, polariscope, and analyser.

The sub-stage consists of a ring casting, having a projecting portion upon it about $\frac{1}{8}$ in. thick. The ring, when turned, is $\frac{3}{4}$ in. deep, and must be perfectly true on the face, and turned inside to such a size ($1\frac{1}{2}$ in. full) that a ring $1\frac{1}{2}$ in. external diameter will slide within it, but will not slip out; the out-

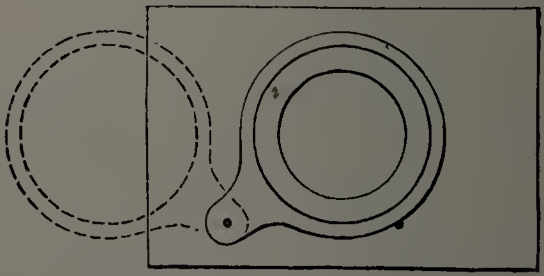


Fig. 118.—Underside of Stage, Showing Two Positions of Sub-stage.

side of the ring may be turned down to about $\frac{1}{24}$ in. thick to reduce the weight, leaving the upper portion, the width of the projecting piece, a little thicker. The projecting portion is for fixing to the underside of the microscope stage, and will require filing into shape (Figs. 118 and 119). The sub-stage, being of the standard size, will take any other fitting made of the standard size; that is, $1\frac{1}{2}$ in.

With regard to the fitting for the polariscope, a piece of tubing is now required $1\frac{1}{2}$ in. external diameter and $\frac{3}{4}$ in. wide; this can be bought. If it is a trifle over $1\frac{1}{2}$ in., turn it down to the proper size. Now cut out a circle of sheet brass $1\frac{3}{4}$ in. diameter, and exactly in the centre bore a hole $\frac{3}{4}$ in. in diameter; this will require enlarging slightly

to take the polariscope. Braze or solder the circle to the ring (Fig. 120).

The polariscope consists of two pieces of tubing, one of which will slide easily within the other; the inner tube is $\frac{3}{4}$ in. external diameter and $1\frac{1}{4}$ in. long, and as it will be found difficult to get a tube to fit over this, a piece of tubing may be taken $\frac{7}{8}$ in. external diameter and 1 in. long. Cut it open lengthways by means of a fret saw, file a little off each face of slit, and solder or braze together again. It will now be a trifle too small; the smaller tube may be turned down outside until they fit (Fig. 121).

Another portion of the larger tube may be treated in the same way and cut into two rings, each $\frac{1}{8}$ in. wide. Braze or solder one of them on to one end of small tube; on the other ring, inside, get a thread

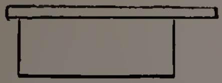


Fig. 119.—Sub-stage.

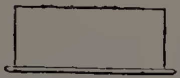


Fig. 120.—Ring and Circular Plate.

turned, and a corresponding male thread on the other end of small tube. Now cut out a circle in sheet brass 1 in. diameter, and in the centre drill a hole $\frac{5}{8}$ in. diameter; solder or braze this circle on to the ring with thread cut upon it, and it will then form a kind of cap, screwing on to the smaller tube. Place the larger tube on to the smaller one, and then screw on the cap. When screwed up tight it should allow the outer tube to move round easily; a drop of oil will help it to do this.

The polariscope tube is now finished (Fig. 122). Solder or braze it into the hole which has been made for it in the $1\frac{1}{2}$-in. ring, having the top of the polariscope flush with the top of the ring, and the screw cap outside (Fig. 123).

The analyser (Fig. 124) can now be made. Fig. 124 shows a plain piece of tube similar to the smaller

tube of the polariser, with a thread cut on one end to fit the thread which is usually cut inside of the objective, and it is screwed into the objective before screwing it on to the tube of the microscope, and of course goes inside the tube. If there is no thread

Fig. 121.

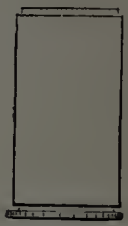


Fig. 122.

Figs. 121 and 122.—Polariscope Tubes.

inside the objective, then some other method of fixing must be devised; even placing on top of objective will do.

The two prisms of Iceland spar had better be bought; the amateur is not advised to try to cut and polish and cement them. The prisms are fixed in the tubes by cutting a cork in two, cutting out the centre of the shape of the prism, and putting the whole thing, cork and prism, into the tube,

Fig. 123.

Fig. 124.

Fig. 123.—Polariscope and Ring Combined. Fig. 124. —Analyser.

taking care that the prism is exactly in the centre of the tube; if a thin glass circle is cemented on to each end of the corks, it will prevent dust and moisture getting to the prisms.

The difficulty now will be the fixing of the sub-

stage to the stage of the microscope. Drill a small hole in the projecting portion of the sub-stage for the screw to pass through; glue to the upper face of the sub-stage a sheet of paper, and make a small hole directly in the centre of the ring (this can be done with compasses). Fasten the sub-stage to the underside of stage by means of clamps somewhere about the right position, and having a moderately strong objective, look for the pinhole in the paper, move the sub-stage until it comes into view, and bring it directly in the centre of the field; the pinhole will now look more like the crater of a volcano than a pinhole. But, however, proceed. Having got the pinhole right in the centre of the field, with a steel point placed in the hole in the projecting portion of the sub-stage, make a mark on the stage, and bore the hole there, not quite through; tap it, and having filed the screw to the proper length, screw on the sub-stage. Also fix a peg for it to rest against when in proper position (*see* Fig. 118).

It is important that the sub-stage be properly centred, otherwise on revolving the polariscope the field of view does not appear properly dark and light, which is essential for good work.

CHAPTER XII.

A CAMERA LUCIDA FOR THE MICROSCOPE.

Dr. Wollaston's camera lucida is an optical instrument which facilitates the delineation of an object. The camera lucida, as invented by Dr. Wollaston, when attached to the microscope, is found to be a little inconvenient, as it is necessary to keep the head in a fixed position, because the proportion between the size of the tracing and the object is affected by the distance of the eye from the paper. If the microscope is placed upon a support of a different height, or if the eyepiece is lowered or depressed by a slight inclination of the body, the scale is proportionally altered, thus rendering inaccurate drawings made of the details discovered by the microscope.

Fig. 125, a section of an improved camera lucida of the Zeiss pattern, shows where it differs from the Wollaston lucida. The object being observed in the microscope and the paper and pencil are placed parallel to each other on the table. Then the image P of the paper and pencil coming in a vertical direction is reflected by a large mirror M, in a horizontal direction G, to a cube of glass which has a silvered diagonal plane with a small circular hole in it in the visual point of the eyepiece. The microscope image O is seen directly through this aperture in the silvering of the prism, while the silvered plane of the prism transmits the image of the paper and pencil. Then by the concentricity thus obtained of the bundle of rays reaching the eye at E from both the microscope and the paper, the image and the pencil with which it is to be drawn are seen coincidentally without any straining.

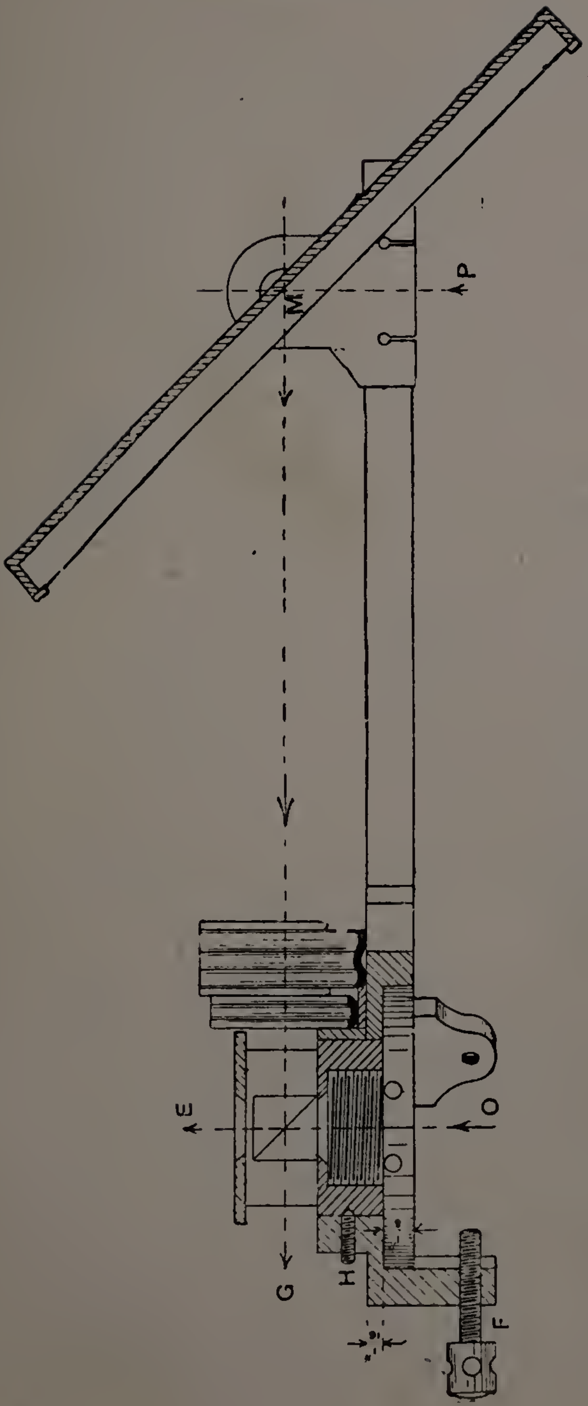


Fig. 125.—Section of Camera Lucida.

The optical system consists, therefore, of the mirror, 3 in. by 2 in. by $\frac{1}{8}$ in., which may be moved to and from the microscope on a square bar of brass, and of a cube of glass which is adjusted over the eyepiece of the microscope. This glass cube consists of two right-angled prisms with their diagonals in contact. The diagonal of one prism is silvered over, with the exception of just a circular portion, $\frac{1}{8}$ in. in diameter, in its centre. The two prisms are then cemented together, forming a cube whose sides are each $\frac{1}{4}$ in. square.

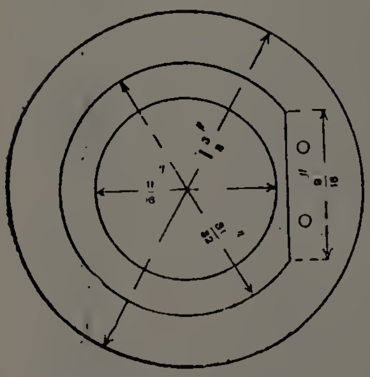


Fig. 126.—Plan of Flange for Camera Lucida.

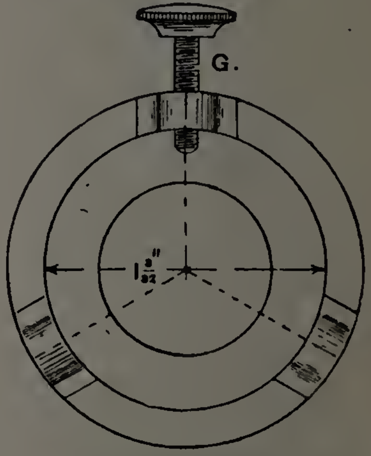


Fig. 127.—Underneath View of Camera Lucida.

The mounting for the prisms consists of three separate pieces. First, there is the flange (Figs. 126 to 128), a circular piece with three equidistant lugs. These lugs carry the screws by means of which the lucida is attached to the microscope and adjusted over the opening of the eyepiece. The flange is first chucked by the smaller end, and turned out to the following dimensions: External diameter, $1\frac{3}{8}$ in.; internal diameter, $1\frac{3}{32}$ in. for a depth of $\frac{1}{8}$ in.; the lugs extend $\frac{5}{16}$ in. beyond this. On the outside the lugs are $\frac{1}{2}$ in. over all (see Fig. 128). A No. 5 B.A. hole is drilled and tapped in each lug.

The edges of the lugs and the surfaces between them are filed to dimensions after the flange has been turned. At the smaller or top end of each flange the dimensions are as follows: External diameter, $\frac{31}{32}$ in.; internal diameter, $\frac{11}{16}$ in.; length, $\frac{3}{16}$ in., making a total length from top end to end of lugs of $\frac{11}{16}$ in.

The screws are made, two of iron and one of German silver. The iron screws F (Fig. 125) are of the capstan-head variety. The screwed part is $\frac{7}{16}$ in. long, and the head is $\frac{3}{16}$ in. long and $\frac{3}{16}$ in. in diameter, the head being drilled through with holes at right angles. The German silver screw G (Fig. 127) is similar, and has a head $\frac{3}{8}$ in. in diameter, with the edge milled, the shoulder against which

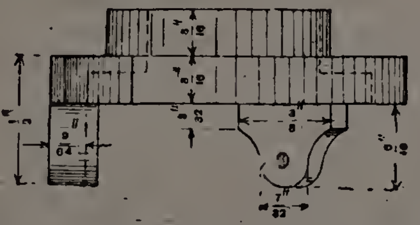


Fig. 128.—Side Elevation of Camera Lucida.

the screw terminates being $\frac{3}{16}$ in. diameter. The lug on which this screw is fixed is the one nearest the operator, and Fig. 127, being an illustration of the flange upside down, shows the lug on the farther side.

It will be seen from Figs. 125 and 126 that a portion of the upper part of the flange is cut away. This makes room for a couple of frames for holding dark glasses, which are screwed down at right angles to the optical axis of the lucida. The centre of this flattened part is at the opposite end of the diameter which terminates in the end lug. The length of the flat is $\frac{9}{16}$ in., and the bottom is made level with the turned surface. The position for the screw-holes is found when the frames are ready for mounting.

The second piece of the instrument is the prism case or cell, illustrated by Figs. 125, 129 and 130; Figs. 125 and 130 are sections at A A (Fig. 129) and B B respectively. The diameter being $\frac{11}{16}$ in., the piece fits the flange hole and is kept in position

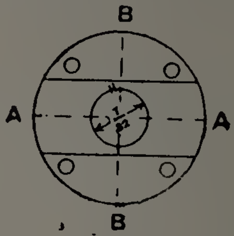


Fig. 129.—Plan of Prism Cell.

by the No. 7 B.A. iron grub screw H (Fig. 125). One end of this screw is blunt pointed, and enters a V-shaped recess in the prism case; the other end is rounded and notched. The hole in the flange is drilled when the adjustment of the prism in the case has been effected so that the same drill may make the V-shaped recess in the prism case. This hole is subsequently tapped out No. 7 B.A., and its edges are chamfered with a larger drill. At the bottom end the metal of the prism case is bored $\frac{7}{16}$ in. to a depth of $\frac{7}{32}$ in., and screwed thirty-two

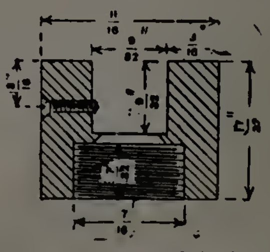


Fig. 130.—Section of Prism Cell.

threads to the inch. This is necessary to obtain accuracy in the centering of the prism. The case is screwed to an adapter, and the prism is moved about one way or another until the little hole in the centre of the silvered diagonal runs quite true

when revolved in the lathe. At the top or prism end there are two walls, separated by $\frac{9}{32}$ in., a thickness of $\frac{1}{32}$-in. metal being left as the base on which the glass cube rests. When turning and screwing the bottom end of the casting a $\frac{7}{32}$-in. hole is drilled

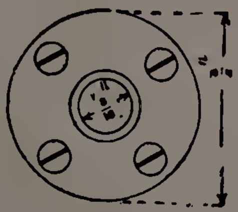


Fig. 131.—Plan of Cover.

through this base, and chamfered to a sharp edge (see Fig. 125). In one of the walls—it does not matter much which—a No. 7 B.A. hole is drilled and tapped to receive a No. 7 B.A. iron taper-head screw, which keeps the prism in its place. Two pieces of cork are placed between the cube and the walls, one on each side. The centering of the cube is a tedious process, but much depends on the accuracy with which it is done.

A third piece, shown in section at Fig. 125 and in plan at Fig. 131, is a cover with an eye-hole for the prism. This cover is a disc of brass $\frac{1}{32}$ in. thick,

Fig. 132.—Plan of Large Frame for Dark Glass.

turned on both sides and secured to the prism case by four No. 7 B.A. iron screws. When screwed down as concentrically as possible the edge of the disc is turned down to a diameter of $\frac{3}{4}$ in., and a $\frac{1}{16}$-in. hole is drilled in the centre and chamfered

to a sharp edge. Two metal frames (Figs. 132 to 135) for holding dark glasses complete this half of the lucida. In Fig. 125 they are shown mounted between the mirror and the prism, and it will be seen that the larger frame extends beyond the flange,

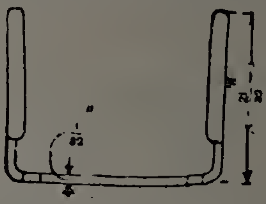


Fig. 133.—Side Elevation of Large Frame for Dark Glass.

whilst the smaller one presses close up against the flat filed on the flange. Figs. 132 and 133 illustrate the larger frame, which is made of $\frac{1}{32}$-in. sheet brass pressed to shape, and contains two sockets. The upright ends, seen from above, look not unlike flattened figures 3, and in section the bottom has also the same appearance.

Fig. 136 shows a simpler form of large frame. To make it, obtain a piece of sheet brass $2\frac{1}{8}$ in. by $\frac{7}{16}$ in. by $\frac{1}{32}$ in., file it square and parallel, and across its width scribe a centre line. Now, with the

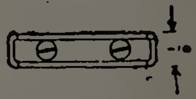


Fig. 134.

Fig. 135.

Figs. 134 and 135.—Plan and Side Elevation of Small Frame.

dividers, mark off other lines on either side of this centre—two lines $\frac{3}{8}$ in. on each side, two $\frac{9}{16}$ in., and two $\frac{9}{32}$ in.—and line them in across the width. Now along the length draw three lines—one $\frac{1}{32}$ in. from the edge, the second $\frac{7}{32}$ in. from the same edge,

and the third $\frac{1}{4}$ in. from the same edge. Then file the metal down to the line $\frac{1}{32}$ in. from the edge between the two lines that were marked off at $\frac{9}{16}$ in. on each side of the centre. This will leave a projection at each end of $\frac{7}{32}$ in. At the opposite edge file the metal at the ends to the $\frac{1}{4}$-in. line, ending on each side at the two lines marked off $\frac{3}{8}$ in. from the centre. This will leave a projection in the middle $\frac{3}{16}$ in. wide by $\frac{3}{4}$ in. long. Next file two recesses down to the line drawn $\frac{7}{32}$ in. from the edge, one on each side of this projection, between the lines $\frac{9}{16}$ in. and $\frac{3}{4}$ in. from the centre. This will give two $\frac{1}{32}$-in. projections at the ends similar to those produced at the first edge. File two equal curves at each end of the middle projection, joining

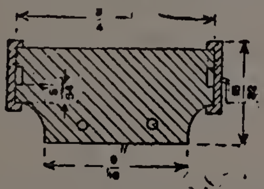


Fig. 136.—Alternative Form of Large Frame.

the ends of the $\frac{3}{8}$-in. lines with the ends of the $\frac{9}{32}$-in. lines. This reduces the end of the projection to a length of $\frac{9}{16}$ in., and gives it the appearance shown in Fig. 136. Get a piece of iron, filed square and parallel, $\frac{3}{4}$ in. by $\frac{3}{4}$ in. by $\frac{7}{32}$ in., place it on the sheet brass centrally, and bend up the ends at the lines drawn $\frac{3}{8}$ in. from the centre. The ends must stand perfectly square with the bottom, and it will be necessary to use a flat hammer to attain this end. Nip the upright ends with the iron between them in the vice, bend over the four $\frac{1}{32}$-in. projections, and flatten and square them on a surface plate with the hammer. Seen from above this frame will appear like Fig. 136, except that it will have one wide socket instead of two narrow ones. Now get two strips of brass, each $\frac{11}{16}$ in. by $\frac{1}{8}$ in. by $\frac{1}{32}$ in., and either pin or solder one in the middle of each

upright. This will give the required double socket, and the uprights will only need trimming up at the ends or perhaps reducing a little till each stands $\frac{31}{32}$ in. high. If desired, the corners may be rounded as in Fig. 133.

The second frame is smaller, but may be made in a similar manner, or as in Figs. 134 and 135. The dimensions are as follows: Width, $\frac{1}{8}$ in.; length of uprights, $\frac{9}{16}$ in.; distance between them, $\frac{1}{2}$ in.; thickness of metal, $\frac{1}{32}$ in.; and depth of recess about $\frac{1}{32}$ in., whether square or rounded. At the bottom of this frame two plain screw-holes are drilled and chamfered for two No. 9 B.A. taper-head screws (see Fig. 134). When drilled, this frame is placed centrally over the bottom projection of the larger

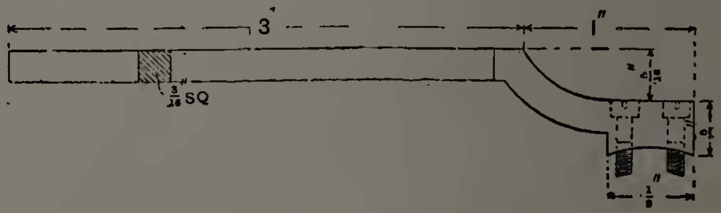


Fig. 137.—Plan of Bar for Camera Lucida.

frame; and the positions of the holes are marked off with a scriber. When these have been drilled, the large frame is placed in position against the flat on the flange, and the holes shown in Fig. 126 are similarly marked off. The holes in the two frames are clearance holes, but in the flange they are drilled and tapped. No. 9 B.A. iron screws are used.

It is necessary to offer a word of explanation as to the use of the dark glasses for which the frames have been made. When the camera lucida is in use it is often found that the reflected light from the paper is too strong—in fact, it may overpower the light from the object. When this is the case, it is not advisable, nor is it always convenient, to lessen the light on the paper. The desired end is

gained by interposing a number of tinted glasses between the rays reflected by the mirror and the diagonal reflecting surface of the prism. For this reason three dark glasses are supplied with each instrument.

The second part of the instrument consists of the mirror, its carrier, and the bar on which it travels. The bar (Fig. 137) is $\frac{3}{16}$ in. square for $2\frac{7}{8}$ in. of its length, its total length being 4 in. The thickness

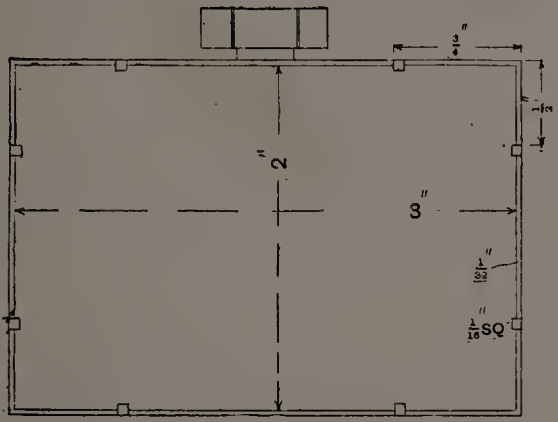


Fig. 138.

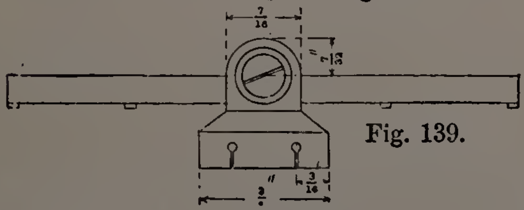


Fig. 139.

Figs. 138 and 139.—Plan and Side Elevation of Mirror Frame and Carrier.

of the metal throughout is $\frac{3}{16}$ in. The under curve begins at a point $2\frac{7}{8}$ in. from the end of the bar, and the inner side is turned to such a radius that it fits over the largest part of the flange. The holes are drilled and countersunk at this end to receive the two No. 5 B.A. cheese-head screws which fasten the bar to the flange. To find the correct place on the flange at which the holes must be drilled to receive these screws, place the flange

on its chuck and draw four equidistant lines on its circumference. Two of these lines will be at the ends of a diameter connecting the dark-glass frames and a lug of the flange. The other two lines will be at the ends of a diameter at right angles to the first. The bar must be screwed down so that it is exactly parallel to the first diameter, and at the right-hand end of the second diameter. The position is indicated by the holes of the screws, which show on the inner circumference of the flange, on either side of the optic axis.

Figs. 138 to 140 illustrate details of the mirror and carrier. The mirror frame is $\frac{1}{32}$ in. thick throughout, and is 3 in. by 2 in. by $\frac{1}{8}$ in. deep to suit the mirror. On each side are two clips which hold the mirror; these are projections $\frac{1}{16}$ in. square, which

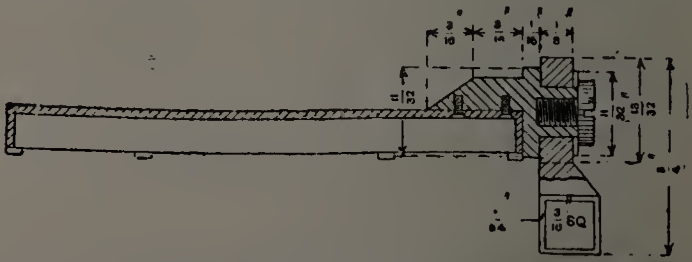


Fig. 140.—Cross Section of Mirror Frame and Carrier.

are thinned previous to being pressed over the mirror. The method by which the mirror frame is attached to the carrier is illustrated by Fig. 140, which is a cross section of both. One end of a connecting piece forms an axis for the carrier, whilst to the other end a mirror frame is screwed. The carrier is made of two pieces soldered together. The bottom part is a piece of square-drawn tubing which slides on the bar, and which therefore is $\frac{3}{16}$ in. square internally. It is $\frac{3}{4}$ in. long, and rather more than $\frac{1}{64}$ in. thick. On one side a casting, shaped as in Figs. 139 and 140, is soldered. On two opposite sides of the sliding tube four holes are

drilled, the centres of which are $\frac{1}{8}$ in. from the bottom and $\frac{3}{16}$ in. from each end. The opposite holes are then connected by the tube being sprung or sawn across the bottom, as in Fig. 138. Should there be any slackness in the motion of the sliding tube on the bar, the middle part is pressed inwards and acts as a spring.

The connecting piece is made of $\frac{3}{8}$-in. stick brass. First, the metal is reduced to a parallel diameter of $\frac{11}{32}$ in.; then a length of rather more than $\frac{1}{8}$ in. is reduced to a diameter of $\frac{3}{16}$ in. to fit the hole in the carrier. Next a No. 4 B.A. hole is concentrically drilled and tapped. The edge is chamfered, and the carrier worked on till the motion is free and even. Then the German silver washer and screw are placed in position and tried. The washer is about $\frac{1}{64}$ in. thick, has a $\frac{3}{16}$-in. central hole, and is $\frac{11}{32}$ in. in diameter. The edge is rounded and burnished; after which the washer is slightly bent across the middle, so that it will act as a spring. The screw is made of brass, and has a cheese-head $\frac{1}{4}$ in. in diameter and $\frac{1}{16}$ in. thick.

The metal of the connecting piece is left $\frac{11}{32}$ in. in diameter for $\frac{1}{16}$ in., then for a length of $\frac{3}{16}$ in. it is reduced to a diameter of $\frac{1}{4}$ in.; and then for a further length of $\frac{3}{16}$ in. it is tapered down to a point, being thus severed from the body of the stick. Previous to cutting it off completely, two lines are marked off at the opposite ends of a diameter at this end. When severed, half the metal at this end is filed away; that is, down to these lines. This flat must be central and true, so that when screwed by two No. 9 B.A. screws to the frame, it should project squarely from the edge. The position of the connecting piece on the frame must be central. This is indicated at Fig. 139, though the carrier, which is central, hides the piece behind it. On this central line, when found, one clearance hole is drilled as near to the side of the frame as possible, and is

countersunk deep enough to allow the screw-head to sink below the surface. The centre of the second hole is $\frac{3}{16}$ in. from that of the first. It is similarly countersunk. Then the positions of the holes are marked off on the connecting piece, and the No. 9 B.A. holes are drilled and tapped.

When the various parts have been made, they are grained with emery paper, bronzed, and lacquered. The iron screws are polished and then blued in Calais sand or over a Bunsen flame, and lacquered. The German silver screw and washer and the brass screw are polished and lacquered. After bronzing, the interior of the sliding tube of the carrier is cleaned out, and the bar on which it slides is straight grained and dulled with tallow. This prevents it tarnishing unevenly. The bronzed part of the bar extends $\frac{1}{16}$ in. beyond the end of the under curve. After bronzing, the prism is adjusted in its cell.

When the camera lucida for the microscope is to be used, very fine adjustment is necessary, and the operator must not be discouraged if at first he does not obtain very good results. The eye has to become accustomed to receiving light from two different sources, and the light itself has to be equalised. The prism must be adjusted perfectly true to the optical axis of the microscope, and this is a work of time. But once adjusted, the capstan-head screws need not be touched on removal of the lucida. The thumbscrew is loosened sufficiently for that purpose, and consequently there is considerably less adjustment necessary on using the instrument a second time. Of course, the paper must be placed in a plane parallel to that of the object; thus, if the microscope is vertical, the paper must be horizontal, and *vice versa*. In either case the image is presented precisely as seen in the microscope.

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